THE No 1 UK MAGAZINE FOR ELECTRONICS TECHNOLOGY & COMPUTER PROJECTS

EPE EVERYDAY PRACTICAL ELECTRONICS

www.epemag.com

LAB-STANDARD 16-BIT DIGITAL POTENTIOMETER

16-BIT DIGITAL POTENTIOMETER

- Works with AC or DC
- Directly programmable via a keypad
- 16-bit resolution, giving 65,535 steps
- Uses just 4.5W from a 12V supply

WIN ONE OF THREE MICROCHIP PICDEM 2 PLUS BOARDS

INTELLIGENT 12V FAN CONTROLLER

Cool things down this summer!

Jump Start

Battery Voltage Checker

More fun from our exciting new series for newcomers to electronics

DUAL TRACKING ±0V TO 19V POWER SUPPLY – PART 2

Assembling our high quality bench supply

$9.99US £4.40UK
JULY 2012 PRINTED IN THE UK

PLUS

PRACTICALLY SPEAKING, PIC N' MIX, NET WORK, CIRCUIT SURGERY, READOUT, TECHNO TALK

spend £10 or over and choose	 **12in1 Screwdriver** Coupon Code - ESD001	or **Sidecutters** Coupon Code - ESC002	or **10% off your order value** **10% Off** Coupon Code - ETE003
spend £25 or over and choose	 **Pocket Multimeter** Coupon Code - EPM004	or **26pc Tool Kit** Coupon Code - ETK005	or **10% off your order value** **10% Off** Coupon Code - ETE003
spend £50 or over and choose	 **Wire Strippers** Coupon Code - EWS006	or **Helping Hands** Coupon Code - EHH007	or **10% off your order value** **10% Off** Coupon Code - ETE003
spend £75 or over and choose	 **Pro S8 Multimeter** Coupon Code - EMU008	or **25W Soldering Iron** Coupon Code - ESO009	or **10% off your order value** **10% Off** Coupon Code - ETE003

A Choice Of FREE GIFT

With All Orders Of £10 Or More

To qualify for a free gift, place an order of at least £10, £25, £50 or £75 at spiratronics.com. Depending on your spend, you'll qualify for a free gift from the three options indicated in the table shown above. To claim, simply enter the corresponding coupon code of your selected free gift at the checkout stage.

visit us at...
spiratronics.com
for our comprehensive range

- Thousands of low cost, high quality products
- Same day dispatch on orders before 3pm
- Low, flat postage cost (£1.49 for UK) on all orders with no minimum order value

Spiratronics

*Please note, only one free gift can be claimed per transaction. Only valid from spiratronics.com. Expires 31/07/2012. E&OE.

ISSN 0262 3617
● PROJECTS ● THEORY ●
● NEWS ● COMMENT ●
● POPULAR FEATURES ●
VOL. 41. No 7 July 2012

EPE EVERYDAY PRACTICAL ELECTRONICS

INCORPORATING ELECTRONICS TODAY INTERNATIONAL

www.epemag.com

Projects and Circuits

LAB-STANDARD 16-BIT DIGITAL POTENTIOMETER by Jim Rowe 10
A low-cost digital 'programmable' voltage divider

INTELLIGENT 12V FAN CONTROLLER by Geoff Graham 24
Control up to eight computer fans based on measured temperature

DUAL TRACKING ±0V TO 19V POWER SUPPLY – PART 2 34
by Nicholas Vinen
Assemble, house and wire up this high quality linear bench supply

Series and Features

TECHNO TALK by Mark Nelson 22
How do they do it?

JUMP START by Mike and Richard Tooley 48
Design and build a simple Battery Voltage Checker

PIC N' MIX by Mike Hibbett 56
Video for the chipKIT Uno32

CIRCUIT SURGERY by Ian Bell 60
Output buffers

PRACTICALLY SPEAKING by Robert Penfold 64
Be patient...

NET WORK by Alan Winstanley 70
Click here to send... Snap to it... Taxing times... Get some back-up...
Google Drives your way

MAX'S COOL BEANS by Max The Magnificent 74
A touch of style... Apple TV... Wireless Boombox

Regulars and Services

EDITORIAL 7
Don't let electrical familiarity breed contempt

NEWS – Barry Fox highlights technology's leading edge 8
Plus everyday news from the world of electronics

SUBSCRIBE TO *EPE* and save money 23

MICROCHIP READER OFFER 58
EPE Exclusive – Win one of three Microchip PICDem 2 Plus Boards

CD-ROMS FOR ELECTRONICS 67
A wide range of CD-ROMs for hobbyists, students and engineers

READOUT – Matt Pulzer addresses general points arising 72

DIRECT BOOK SERVICE 75
A wide range of technical books available by mail order, plus more CD-ROMs

***EPE* PCB SERVICE** 78
PCBs for *EPE* projects

ADVERTISERS INDEX 79

NEXT MONTH! – Highlights of next month's *EPE* 80

© Wimborne Publishing Ltd 2012. Copyright in all drawings, photographs and articles published in *EVERYDAY PRACTICAL ELECTRONICS* is fully protected, and reproduction or imitations in whole or in part are expressly forbidden.

Our August 2012 issue will be published on Thursday 5 July 2012, see page 80 for details.

Readers' Services • Editorial and Advertisement Departments 7

QUASAR
electronics
Solutions for Home, Education & Industry Since 1993

Quasar Electronics Limited
PO Box 6935, Bishops Stortford
CM23 4WP, United Kingdom
Tel: 01279 467799
Fax: 01279 267799
E-mail: sales@quasarelectronics.com
Web: www.quasarelectronics.com

All prices INCLUDE 20.0% VAT.
Postage & Packing Options (Up to 0.5Kg gross weight): **UK Standard 3-7 Day Delivery** - £4.95; **UK Mainland Next Day Delivery** - £11.95; **Europe (EU)** - £12.95; **Rest of World** - £14.95 (up to 0.5Kg).
!Order online for reduced price Postage (from just £1)
Payment: We accept all major credit/debit cards. Make PO's payable to Quasar Electronics.
Please visit our online shop now for full details of over 500 electronic kits, projects, modules and publications. Discounts for bulk quantities.

01279 Credit Card Sales 467799

PIC & ATMEL Programmers

We have a wide range of low cost PIC and ATMEL Programmers. Complete range and documentation available from our web site.

Programmer Accessories:
40-pin Wide ZIF socket (ZIF40W) £14.95
18Vdc Power supply (PSU121) £24.95
Leads: Parallel (LDC136) £3.95 / Serial (LDC441) £3.95 / USB (LDC644) £2.95

USB & Serial Port PIC Programmer

USB/Serial connection. Header cable for ICSP. Free Windows XP software. See website for PICs supported. ZIF Socket and USB lead extra. 18Vdc.
Kit Order Code: 3149EKT - **£49.95**
Assembled Order Code: AS3149E - **£59.95**
Assembled with ZIF socket Order Code: AS3149EZIF - **£74.95**

USB Flash/OTP PIC Programmer

USB PIC programmer for a wide range of Flash & OTP devices—see website for details. Free Windows Software. ZIF Socket and USB lead not included. Supply: 16-18Vdc.
Assembled Order Code: AS3150 - **£49.95**
Assembled with ZIF socket Order Code: AS3150ZIF - **£64.95**

ATMEL 89xxxx Programmer

Uses serial port and any standard terminal comms program. 4 LED's display the status. ZIF sockets not included. Supply: 16Vdc.
Kit Order Code: 3123KT - **£28.95**
Assembled Order Code: AS3123 - **£39.95**

Introduction to PIC Programming

Go from complete beginner to burning a PIC and writing code in no time! Includes 49 page step-by-step PDF Tutorial Manual, Programming Hardware (with LED test section), Win 3.11—XP Programming Software (Program, Read, Verify & Erase), and 1rewritable PIC16F84A that you can use with different code (4 detailed examples provided for you to learn from). PC parallel port.
Kit Order Code: 3081KT - **£16.95**
Assembled Order Code: AS3081 - **£24.95**

PIC Programmer Board

Low cost PIC programmer board supporting a wide range of Microchip® PIC™ microcontrollers. Requires PC serial port. Windows interface supplied.
Kit Order Code: K8076KT - **£39.95**

PIC Programmer & Experimenter Board

The PIC Programmer & Experimenter Board with test buttons and LED indicators to carry out educational experiments, such as the supplied programming examples. Includes a 16F627 Flash Microcontroller that can be reprogrammed up to 1000 times for experimenting at will. Software to compile and program your source code is included.
Kit Order Code: K8048KT - **£39.95**
Assembled Order Code: VM111 - **£59.95**

Controllers & Loggers

Here are just a few of the controller and data acquisition and control units we have. See website for full details. 12Vdc PSU for all units: Order Code PSU303 £9.95

USB Experiment Interface Board

5 digital input channels and 8 digital output channels plus two analogue inputs and two analogue outputs with 8 bit resolution.
Kit Order Code: K8055KT - **£39.95**
Assembled Order Code: VM110 - **£64.95**

Rolling Code 4-Channel UHF Remote

State-of-the-Art. High security. 4 channels. Momentary or latching relay output. Range up to 40m. Up to 15 Tx's can be learnt by one Rx (kit includes one Tx but more available separately). 4 indicator LED 's. Rx: PCB 77x85mm, 12Vdc/6mA (standby). Two *& Ten Channel versions also available.*
Kit Order Code: 3180KT - **£54.95**
Assembled Order Code: AS3180 - **£64.95**

Computer Temperature Data Logger

Serial port 4-channel temperature logger. °C or °F. Continuously logs up to 4 separate sensors located 200m+ from board. Wide range of free software applications for storing/using data. PCB just 45x45mm. Powered by PC. Includes one DS1820 sensor.
Kit Order Code: 3145KT - **£24.95**
Assembled Order Code: AS3145 - **£31.95**
Additional DS1820 Sensors - **£4.95 each**

Remote Control Via GSM Mobile Phone

Place next to a mobile phone (not included). Allows toggle or auto-timer control of 3A mains rated output relay from any location with GSM coverage.
Kit Order Code: MK160KT - **£14.95**

Most items are available in kit form (KT suffix) or pre-assembled and ready for use (AS prefix).

4-Ch DTMF Telephone Relay Switcher

Call your phone number using a DTMF phone from anywhere in the world and remotely turn on/off any of the 4 relays as desired. User settable Security Password, Anti-Tamper, Rings to Answer, Auto Hang-up and Lockout. Includes plastic case. 130 x 110 x 30mm. Power: 12Vdc.
Kit Order Code: 3140KT - **£79.95**
Assembled Order Code: AS3140 - **£94.95**

8-Ch Serial Port Isolated I/O Relay Module

Computer controlled 8 channel relay board. 5A mains rated relay outputs and 4 opto-isolated digital inputs (for monitoring switch states, etc). Useful in a variety of control and sensing applications. Programmed via serial port (use our new Windows interface, terminal emulator or batch files). Serial cable can be up to 35m long. Includes plastic case 130x100x30mm. Power: 12Vdc/500mA.
Kit Order Code: 3108KT - **£74.95**
Assembled Order Code: AS3108 - **£89.95**

Infrared RC 12–Channel Relay Board

Control 12 onboard relays with included infrared remote control unit. Toggle or momentary. 15m+ range. 112 x 122mm. Supply: 12Vdc/0.5A
Kit Order Code: 3142KT - **£64.95**
Assembled Order Code: AS3142 - **£74.95**

Audio DTMF Decoder and Display

Detect DTMF tones from tape recorders, receivers, two-way radios, etc using the built-in mic *or* direct from the phone line. Characters are displayed on a 16 character display as they are received and up to 32 numbers can be displayed by scrolling the display. All data written to the LCD is also sent to a serial output for connection to a computer. Supply: 9-12V DC (Order Code PSU303). Main PCB: 55x95mm.
Kit Order Code: 3153KT - **£37.95**
Assembled Order Code: AS3153 - **£49.95**

3x5Amp RGB LED Controller with RS232

3 independent high power channels. Preprogrammed or user-editable light sequences. Standalone option and 2-wire serial interface for microcontroller or PC communication with simple command set. Suitable for common anode RGB LED strips, LEDs and incandescent bulbs. 56 x 39 x 20mm. 12A total max. Supply: 12Vdc.
Kit Order Code: 3191KT - **£27.95**
Assembled Order Code: AS3191 - **£37.95**

Hot New Products!

Here are a few of the most recent products added to our range. See website or join our email Newsletter for all the latest news.

4-Channel Serial Port Temperature Monitor & Controller Relay Board

4 channel computer serial port temperature monitor and relay controller with four inputs for Dallas DS18S20 or DS18B20 digital thermometer sensors (£3.95 each). Four 5A rated relay channels provide output control. Relays are independent of sensor channels, allowing flexibility to setup the linkage in any way you choose. Commands for reading temperature and relay control sent via the RS232 interface using simple text strings. Control using a simple terminal / comms program (Windows HyperTerminal) or our free Windows application software.
Kit Order Code: 3190KT - **£84.95**
Assembled Order Code: AS3190 - **£99.95**

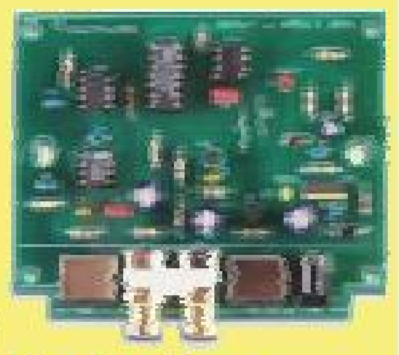
40 Second Message Recorder

Feature packed non-volatile 40 second multi-message sound recorder module using a high quality Winbond sound recorder IC. Standalone operation using just six onboard buttons or use onboard SPI interface. Record using built-in microphone or external line in. 8-24 Vdc operation. Just change one resistor for different recording duration/sound quality. sampling frequency 4-12 kHz.
Kit Order Code: 3188KT - **£29.95**
Assembled Order Code: AS3188 - **£37.95**
120 second version also available

Bipolar Stepper Motor Chopper Driver

Get better performance from your stepper motors with this dual full bridge motor driver based on SGS Thompson chips L297 & L298. Motor current for each phase set using on-board potentiometer. Rated to handle motor winding currents up to 2 Amps per phase. Operates on 9-36Vdc supply voltage. Provides all basic motor controls including full or half stepping of bipolar steppers and direction control. Allows multiple driver synchronisation. Perfect for desktop CNC applications.
Kit Order Code: 3187KT - **£39.95**
Assembled Order Code: AS3187 - **£49.95**

Video Signal Cleaner



Digitally cleans the video signal and removes unwanted distortion in video signal. In addition it stabilises picture quality and luminance fluctuations. You will also benefit from improved picture quality on LCD monitors or projectors.
Kit Order Code: K8036KT - **£32.95**
Assembled Order Code: VM106 - **£49.95**

Most items are available in kit form (KT suffix) or assembled and ready for use (AS prefix).

Motor Speed Controllers

Here are just a few of our controller and driver modules for AC, DC, Unipolar/Bipolar stepper motors and servo motors. See website for full details.

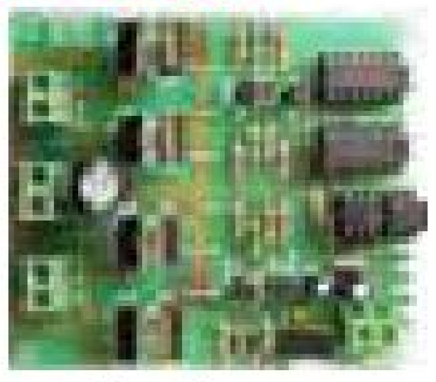
DC Motor Speed Controller (100V/7.5A)

Control the speed of almost any common DC motor rated up to 100V/7.5A. Pulse width modulation output for maximum motor torque at all speeds. Supply: 5-15Vdc. Box supplied. Dimensions (mm): 60Wx100Lx60H.
Kit Order Code: 3067KT - **£19.95**
Assembled Order Code: AS3067 - **£27.95**

Computer Controlled / Standalone Unipolar Stepper Motor Driver

Drives any 5-35Vdc 5, 6 or 8-lead unipolar stepper motor rated up to 6 Amps. Provides speed and direction control. Operates in stand-alone or PC-controlled mode for CNC use. Connect up to six 3179 driver boards to a single parallel port. Board supply: 9Vdc. PCB: 80x50mm.
Kit Order Code: 3179KT - **£16.95**
Assembled Order Code: AS3179 - **£23.95**

Computer Controlled Bi-Polar Stepper Motor Driver



Drive any 5-50Vdc, 5 Amp bi-polar stepper motor using externally supplied 5V levels for STEP and DIRECTION control. Opto-isolated inputs make it ideal for CNC applications using a PC running suitable software. Board supply: 8-30Vdc. PCB: 75x85mm.
Kit Order Code: 3158KT - **£24.95**
Assembled Order Code: AS3158 - **£34.95**

Bidirectional DC Motor Speed Controller

Control the speed of most common DC motors (rated up to 32Vdc/10A) in both the forward and reverse direction. The range of control is from fully OFF to fully ON in both directions. The direction and speed are controlled using a single potentiometer. Screw terminal block for connections.
Kit Order Code: 3166v2KT - **£23.95**
Assembled Order Code: AS3166v2 - **£33.95**

AC Motor Speed Controller (600W)

Reliable and simple to install project that allows you to adjust the speed of an electric drill or 230V AC single phase induction motor rated up to 600 Watts. Simply turn the potentiometer to adjust the motors RPM. PCB: 48x65mm. Not suitable for use with brushless AC motors.
Kit Order Code: 1074KT - **£15.95**
Assembled Order Code: AS1074 - **£23.95**

See www.quasarelectronics.com for lots more motor controllers

QUASAR
electronics
The Electronic Kit Specialists Since 1993

Credit Card Sales 01279 467 799

Electronic Project Labs

Great introduction to the world of electronics. Ideal gift for budding electronics expert!

500-in-1 Electronic Project Lab

Top of the range. Complete self-contained electronics course. Takes you from beginner to 'A' Level standard and beyond! Contains all the hardware and manuals to assemble 500 projects. You get 3 comprehensive course books (total 368 pages) - *Hardware Entry Course*, *Hardware Advanced Course* and a microprocessor based *Software Programming Course*. Each book has individual circuit explanations, schematic and connection diagrams. Suitable for age 12+.
Order Code EPL500 - **£199.95**
Also available: 30-in-1 **£19.95**, 50-in-1 **£29.95**, 75-in-1 **£39.95** £130-in-1 **£49.95** & 300-in-1 **£89.95** (see website for details)

Tools & Test Equipment

We stock an extensive range of soldering tools, test equipment, power supplies, inverters & much more - please visit website to see our full range of products.

Advanced Personal Scope 2 x 240MS/s

Features 2 input channels - high contrast LCD with white backlight - full auto set-up for volt/div and time/div - recorder roll mode, up to 170h per screen - trigger mode: run - normal - once - roll ... - adjustable trigger level and slope and much more.
Order Code: APS230 - **~~£499.95~~ £399.95**

Personal Scope 10MS/s

The Personal Scope is not a graphical multimeter but a complete portable oscilloscope at the size and the cost of a good multimeter. Its high sensitivity - down to 0.1mV/div - and extended scope functions make this unit ideal for hobby, service, automotive and development purposes. Because of its exceptional value for money, the Personal Scope is well suited for educational use.
Order Code: HPS10 - **~~£189.95~~ £159.95**

See website for more super deals!

No.1 FOR KITS

www.quasarelectronics.com

Secure Online Ordering Facilities • Full Product Listing, Descriptions & Photos • Kit Documentation & Software Downloads

Everyday Practical Electronics
FEATURED KITS

July 2012

Everyday Practical Electronics Magazine has been publishing a series of popular kits by the acclaimed Silicon Chip Magazine Australia. These projects are 'bullet proof' and already tested Down Under. All Jaycar kits are supplied with specified board components, quality fibreglass tinned PCBs and have clear English instructions. Watch this space for future featured kits.

Speed Control Kit for Induction Motors

KC-5509 £83.25 plus postage & packing

Ref: Silicon Chip Australia Magazine Apr/Mar 2012

Control induction motors* up to 1.5kW (2HP) to run machinery at different speeds or controlling a pool pump to save money. Also works with 3-phase motors. Full form kit includes case, PCB, hardware and electronics. See website for full features and specifications.

*Note: Does not work for motors with centrifugal switch

Kit will vary from one pictured here.

Full Function Smart Card Reader / Programmer Kit

KC-5361 £20.00 plus postage & packing

This full function programmer allows you to program both the microcontroller and EEPROM in the popular gold, silver and emerald wafer cards. It hooks up to the serial port of your PC and can be operated as a free-standing unit or installed in a PC drive bay. Powered by 9V via a 9 - 12VDC plugpack (use **MP-3146 £6.25**) or 9V battery. Kit supplied with PCB, wafer card socket and all electronic components.

- PCB size: 141 x 101mm

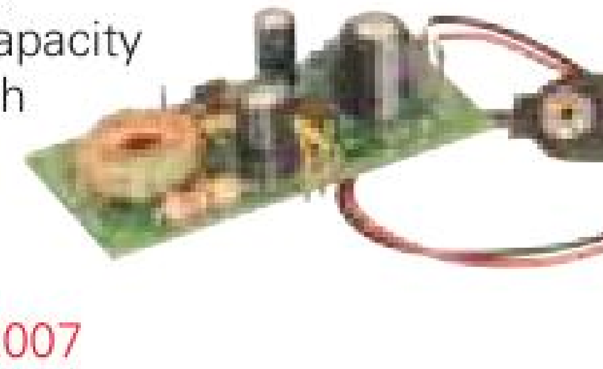
NOTE: Jaycar Electronics and Silicon Chip Magazine will not accept responsibility for the operation of this device, its related software, or its potential to be used for unlawful purposes.

Featured in EPE May 2006

3V - 9V DC to DC Converter Kit

KC-5391 £6.00 plus postage & packing

This great little converter allows you to use regular Ni-Cd or Ni-MH 1.2V cells, or alkaline 1.5V cells for 9V applications. Using low cost, high capacity rechargeable cells, the kit will pay for itself in no-time! You can use any 1.2-1.5V cells you desire. Imagine the extra capacity you would have using two 9000mAh D cells in replacement of a low capacity 9V cell. Kit supplied with PCB, and all electronic components.



- PCB size: 59 x 29mm

Featured in EPE June 2007

Switching Regulator Kit

KC-5508 £14.50 plus postage & packing

Outputs 1.2 to 20V from a higher voltage DC supply at currents up to 1.5A. It is small, efficient and with many features including a very low drop-out voltage, little heat generation, electronic shutdown, soft start, thermal, overload and short circuit protection. Kit supplied with PCB, pre-soldered surface mounted components and all PCB mount components.

- PCB size: 49.5 x 34mm

Audio Project Kits

High Performance 12V Stereo Amplifier

KC-5495 £16.50 plus postage & packing

An ideal project for anyone wanting a compact stereo amp. It could be used for busking or any application where 12V power is available. No mains voltages, so it's safe as a schoolies project or as a beginner's first amp. Performance is excellent with 20WRMS per channel at 14.4V into 4 ohms and THD of less than 0.03%. Shortform kit only. Recommended heatsink (use **HH-8570 £2.25**).

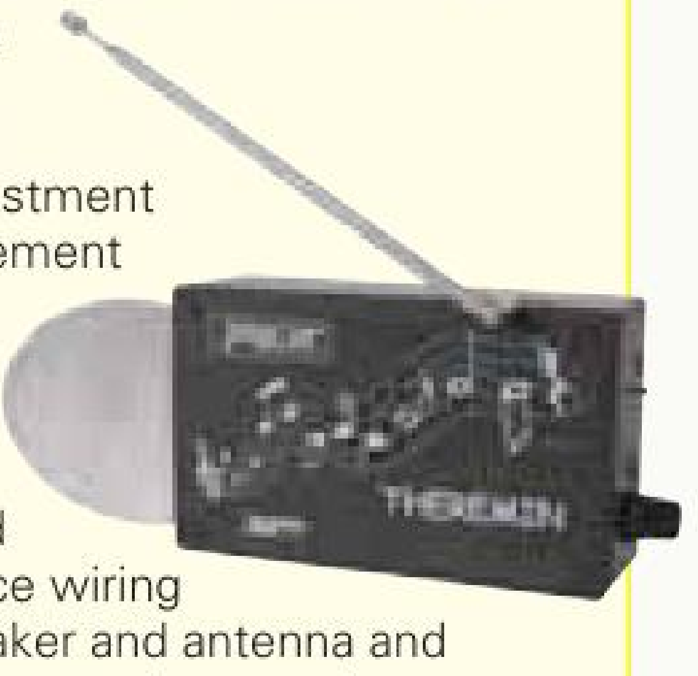
- 12VDC
- PCB size: 95 x 78mm

Featured in EPE May 2012

Theremin Synthesiser Kit MkII

KC-5475 £27.25 plus postage & packing

The ever-popular Theremin is better than ever. It's easier to set up with extra test points for volume adjustment and power supply measurement and it now runs on AC to avoid the interference switchmode plugpacks can cause. It's also easier to build with PCB-mounted switches and pots to reduce wiring to just the hand plate, speaker and antenna and has the addition of a skew control to vary the audio tone from distorted to clean.



- Complete kit contains PCB with overlay, pre-machined case and all specified components

Featured in EPE March 2011

Stereo Digital to Analogue Converter Kit

KC-5487 £50.50 plus postage & packing

If you listen to CDs through a DVD player, you can get sound quality equal to the best high-end CD players with this DAC kit. It has one coaxial S/PDIF input and two TOSLINK inputs to which you can connect a DVD player, set-top box, DVR, computer or any other source of linear PCM digital audio. It also has stereo RCA outlets for connection to a home theatre or Hi-Fi amplifier. See website for full specifications.

- Short form kit with I/O, DAC and switch PCB and on-board components only.
- Requires: PSU (**KC-5418 £7.50**) and toroidal transformer

Featured in EPE Sept/Oct/Nov 2011

The 'Flexitimer'

KA-1732 £7.25 plus postage & packing

Now in it's 3rd revision by Jaycar, the flexitimer remains one of our most versatile short form projects. The flexitimer runs on 12-15V DC and switches the on-board relay once or repeatedly when the switching time is reached. Switching time can be set between 7 seconds and 2 hours in fixed steps.

- PCB size: 74(L) x 47(W)mm

Featured in EPE May/June 2008

Rolling Code Infrared Keyless Entry System

KC-5458 £23.75 plus postage & packing

This keyless entry system features two independent door strike outputs and will recognise up to 16 separate key fobs. The system keeps the coded key fobs synchronised to the receiver and compensates for random button presses while the fobs are out of range. Supplied with solder masked and silk screen printed PCB, two programmed micros, battery and all electronic components.

- Receiver requires a 12VDC 1.5A power supply
- Some SMD soldering is required
- PCB size: 61 x 122mm

Featured in EPE Aug/Sept 2009

Automotive Project Kits

Voltage Monitor Kit

KC-5424 £8.50 plus postage & packing

This versatile kit will allow you to monitor the battery voltage, the airflow meter or oxygen sensor in your car. The kit features 10 LEDs that illuminate in response to the measured voltage, preset 9-16V, 0.-5V or 0-1V ranges, complete with a fast response time, high input impedance and auto dimming for night time driving. Kit includes PCB with overlay, LED bar graph and all electronic components.

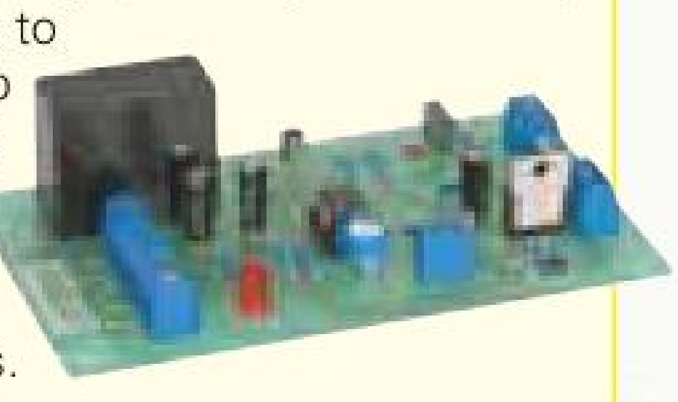
- 12VDC
- Recommended box: UB5 (use **HB6015 £1.25**)

Featured in EPE September 2010

Universal Voltage Switch

KC-5377 £12.00 plus postage & packing

A universal module suits a range of different applications. It will trip a relay when a preset voltage is reached. It can be configured to trip with a rising or falling voltage, so it is suitable for a wide variety of voltage outputting devices eg., throttle position sensor, air flow sensor, EGO sensor. It also features adjustable hysteresis (the difference between trigger on/off voltage), making it extremely versatile. You could use it to trigger an extra fuel pump under high boost, anti-lag wastegate shutoff, and much more. Kit supplied with PCB, and all electronic components.



- PCB size: 105 x 60mm

Featured in EPE December 2010

Wideband Fuel Mixture Controller Kit

KC-5486 £29.00 plus postage & packing

Used for precise engine tuning and can be a permanent installation in the car or a temporary connection to the exhaust tailpipe. Requires Bosch Wideband oxygen sensor LSU4.2.

- 12VDC
- PCB and electronic components
- Programmed PIC
- Case with screen printed lid
- PCB size: 112 x 87mm

Featured in EPE Sept/Oct 2011

Jaycar Electronics

Freecall order: 0800 032 7241

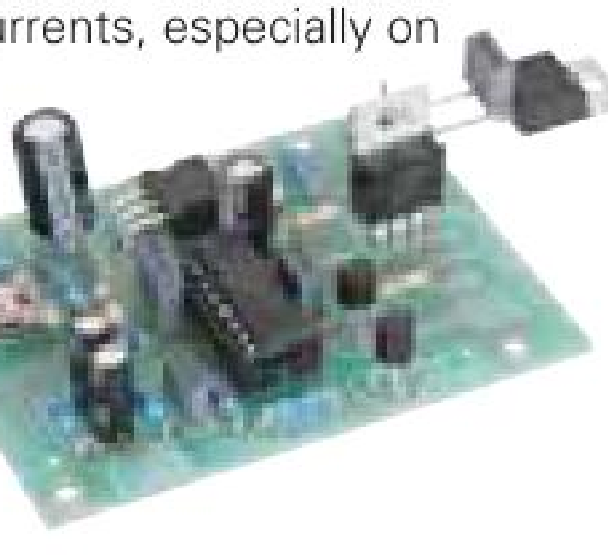
Automotive & Marine Projects for Electronic Enthusiasts

AUTOMOTIVE KITS

10A 12VDC Motor Speed Controller

KC-5225 £11.50 plus postage & packing

Ideal for controlling 12V DC motors in cars such as fuel injection pumps, water/air intercoolers and water injection systems. You can also use it for headlight dimming and for running 12V DC motors in 24V vehicles. The circuit incorporates a soft start feature to reduce inrush currents, especially on 12V incandescent lamps. Includes PCB and all electronic components.



- Kit includes PCB plus all electronic components to build the 10A version.
- PCB size: 69 x 51mm

Speedo Corrector MkII

KC-5435 £20.00 plus postage & packing

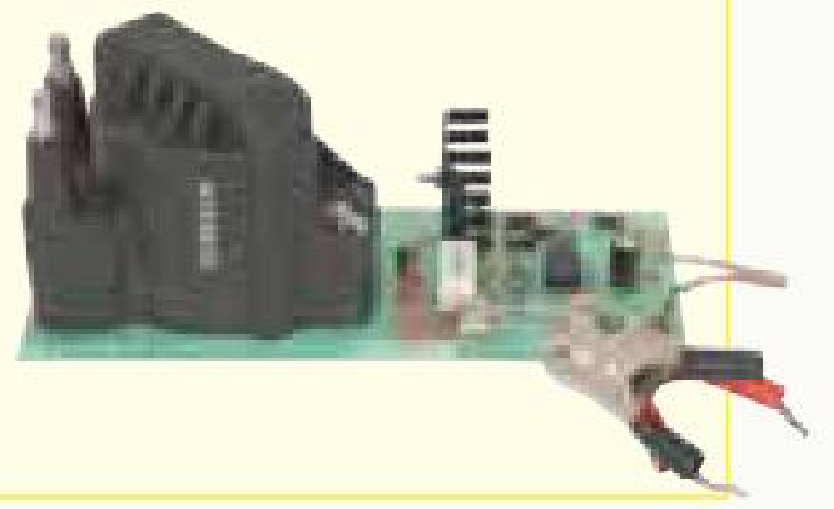
When you modify your gearbox, different ratio or change to a large circumference tyre, it may result in an inaccurate speedometer. This kit alters the speedometer signal up or down from 0% to 99% of the original signal. Also features an LED indicator to show when the input signal is being received. Kit supplied with PCB with overlay and all electronic components.

- Recommended box UB5 (use **HB-6013 £1.50**)
- PCB size: 105 x 61mm

Jacob's Ladder High Voltage Display Kit MK2

KC-5445 £15.75 plus postage & packing

With this kit and the purchase of a 12V ignition coil (available from auto stores and parts recyclers), create an awesome rising ladder of noisy sparks that emits the distinct smell of ozone. This improved circuit is suited to modern high power ignition coils and will deliver a spectacular visual display. Kit includes PCB, pre-cut wire/ladder and all electronic components.



- PCB size: 170 x 76mmm

KIT OF THE MONTH

Ultrasonic Antifouling for Boats

KC-5498 £90.50 plus postage & packing

Marine growth electronic antifouling systems can cost thousands. This project uses the same ultrasonic waveforms and virtually identical ultrasonic transducers mounted in a sturdy polyurethane housings. By building it yourself (which includes some potting) you save a fortune! Standard unit consists of control electronic kit and case, ultrasonic transducer, potting and gluing components and housings. The single transducer design of this kit is suitable for boats up to 10m (32ft); boats longer than about 14m will need two transducers and drivers. Basically all parts supplied in the project kit including wiring. (Price includes epoxies).

- 12VDC
- Suitable for power or sail
- Could be powered by a solar panel/wind generator
- PCB size: 78 x 104mm

Best Seller!

Now available Pre-built:
Dual output, suitable for vessels upto 14m (45ft)
YS-5600 £309.25
Quad output, suitable for vessels upto 20m (65ft)
YS-5602 £412.25

Hand Controller

KC-5386 £24.75 plus postage & packing

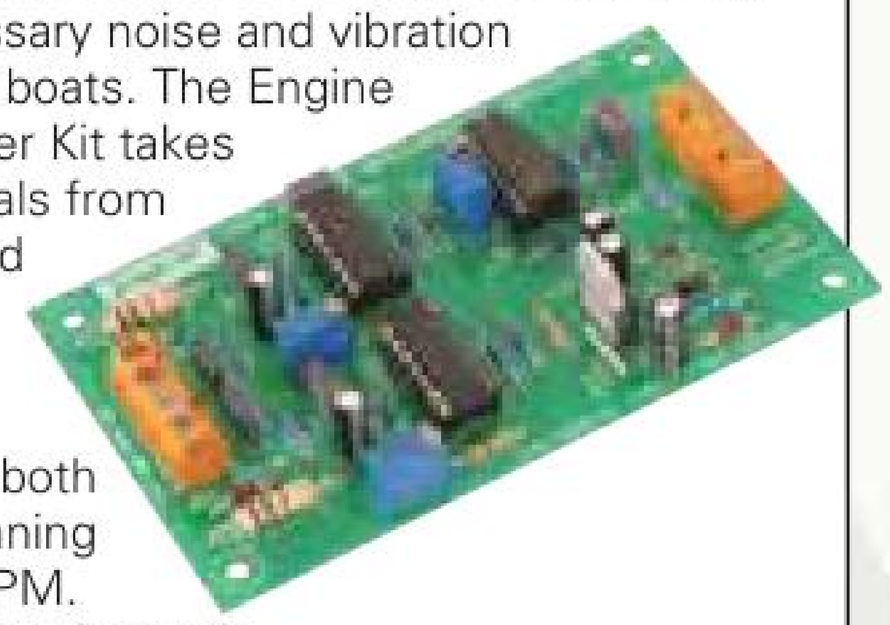
This hand controller is used for the mapping/programming of both Digital Adjuster kits. It features a two line LCD, and easy to use pushbuttons. It can be used to program the adjusters then removed, or left permanently connected to display the adjuster's operation. It is designed as an interface and display, and is not required for general adjuster functions after they have been programmed. If you have built and installed multiple adjuster kits, you will only need one controller to program, unless you want permanent displays for each adjuster function. Kit supplied with silk screened and machined case, PCB, LCD, and all electronic components.

- Must have all D25 pins connected.

Marine Engine Speed Equaliser Kit

KC-5488 £14.50 plus postage & packing

Avoid unnecessary noise and vibration in twin-engine boats. The Engine Speed Equaliser Kit takes the tacho signals from each motor and displays the output on a meter that is centred when both motors are running at the same RPM. When there's a mismatch, the meter shows which motor is running faster and by how much. Simply adjust the throttles to suit. Short form kit only, requires moving coil panel meter (**QP-5010 £6.25**).



- 12VDC
- Kit supplied with PCB, and all electronic components
- PCB size: 105 x 63mm

Mixture Display Kit For Fuel Injected Cars

KC-5195 £6.25 plus postage & packing

This very simple kit will allow you to monitor the fuel mixtures being run by your car. This type of sensor is also known as an E.G.O. (exhaust, gas, oxygen) monitor. The circuit connects to the EGO sensor mounted in the exhaust manifold and the cars battery. PCB, LEDs and components supplied.

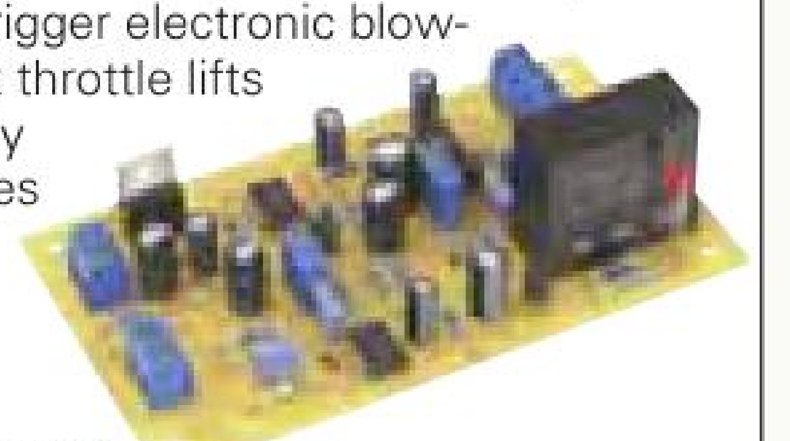
- PCB size: 74 x 36mm

Thousands Sold!

Delta Throttle Timer

KC-5373 £9.25 plus postage & packing

This brilliant design will trigger a relay when the accelerator is pressed or lifted quickly. Used for automatic transmission switching of economy to power modes or trigger electronic blow-off valves on quick throttle lifts etc. It is completely adjustable, and uses the output of a standard throttle position sensor.



- Kit supplied with PCB, and all electronic components

Frequency Switch

KC-5378 £14.00 plus postage & packing

The switch frequency can be set to trip when it is rising or falling, and it features adjustable hysteresis (the difference between trigger on/off frequency). You could configure it to trigger water spray cooling on deceleration, shift light activation, adjustable aerodynamics based on speed, intake manifold switching and much more. It uses a standard tacho, road speed, or many other pulse outputs to switch a relay. Kit supplied with PCB, and all electronic components.

- PCB size: 105 x 60mm

Car Battery Monitor

KA-1683 £8.50 plus postage & packing

Don't get caught with a flat battery! This simple electronic voltmeter lets you monitor the condition of your car's battery so you can act before getting stranded. 10 rectangular LEDs tell you your battery's condition.

- Kit includes PC board and all components
- PCB size: 62 x 39mm

NOW SHIPPING VIA DHL

• FAST DELIVERY • TRACK SHIPMENT

5-10 working day delivery

Post & Packing Charges

Order Value	Cost
£10 - £49.99	£5
£50 - £99.99	£10
£100 - £199.99	£20
£200 - £499.99	£30
£500+	£40

Max weight 550lb
Heavier parcels POA
Minimum order £10

√ We ship via DHL
√ Expect 5-10 days for air parcel delivery
√ Track & Trace parcel

Note: Products are despatched from Australia, so local customs duty & taxes may apply.

How to Order

WEB: www.jaycarelectronics.co.uk
PHONE: 0800 032 7241*
FAX: +61 2 8832 3118*
EMAIL: techstore@jaycarelectronics.co.uk
POST: P.O. Box 107, Rydalmere NSW 2116 Australia

*Australian Eastern Standard Time
(Monday - Friday 09.00 to 17.30 GMT + 10 hours)

All prices in Pounds Sterling. Prices valid until 31/07/2012

Order online: www.jaycarelectronics.co.uk

Jaycar Electronics

velleman

0845 251 4363

cebek

Kit Catalogue Available

UK's No 1 source for VELLEMAN® Kits

Self Assembly Kits & Ready made Modules - See our web site for details on the whole range, Data sheets, Software and more.

www.esr.co.uk

Now Available - Cebek Modules
All modules assembled & tested.

Digital Echo Chamber Kit
A compact sound effects kit, with built-in mic or line in, line out or speaker (500mW). 4 Adjustment controls
Power: 9Vdc 150mA
MK182 Velleman kit £11.43

3rd Brake Light Flasher Kit
Works with any incandescent or LED rear centre brake light. Flashes at 7Hz for 5 or 10 times, adjustable re-triggering.
Power: 12Vdc max load 4A
MK178 Velleman kit £6.30

Digital Clock Mini Kit
Red 7 Segment display in attractive enclosure, automatic time base selection, battery back-up, 12 or 24Hr modes.
Power: 9Vac or dc
MK151 Velleman kit £15.09

Proximity Card Reader Kit
A simple security kit with many applications. RFID technology activates a relay, either on/off or timed. Supplied with 2 cards, can be used with up to 25 cards. Power: 9Vac or dc
MK179 Velleman kit £14.25

Running Microbug Kit
Powered by two subminiature motors, this robot will run towards any light source. Novel shape PCB with LED eyes.
Power: 2 x AAA Batteries
MK127 Velleman kit £9.02

200W Power Amplifier
A high quality audio power amp, 200w music power @ 4Ω 3-200kHz Available as a kit without heatsink or module including heatsink.
K8060 Velleman kit £12.85
Heatsink for kit £9.95
VM100 Module £38.54

MP3 Player Kit
Plays MP3 files from an SD card, supports ID3 tag which can be displayed on optional LCD. Line & headphone output. Remote control add-on. Power: 12Vdc 100mA
K8095 Velleman kit £39.99

DC to Pulse width Modulator
A handy kit to accurately control DC motors etc. Overload & short circuit protection. Input voltage 2.5-35Vdc, Max output 6.5A.
Power: 8-35Vdc
K8004 Velleman kit £9.95

Audio Analyser Kit
A small spectrum analyser with LCD. Suitable for use on 2, 4 or 8Ω systems. 300mW to 1200W(2Ω) 20-20kHz Panel mounting, back-lit display. Power: 12Vdc 75mA
K8098 Velleman kit £31.65

USB DMX Interface
512 DMX Channels controlled by PC via USB. Software & case included. Available as a kit or ready assembled module.
K8062 Velleman kit £47.90
VM116 Module £67.15

USB Interface Board
Featuring 5 in, 8 digital outputs, 2 in & 2 analogue outputs. Supplied with software. Available as a kit or ready assembled module.
K8055 Velleman kit £24.80
VM110 Module £34.90

8 Channel USB Relay Board
PC Controlled 16A relays with toggle, momentary or timed action. Test buttons included, available in a kit or assembled.
K8090 Velleman kit £39.95
VM8090 Module £58.40

Multifunction Up/Down Counter
An up or down counter via on-board button or ext input. Time display feature. Alarm count output. 0-9999 display.
Power: 9-12Vdc 150mA
K8035 Velleman kit £17.85

Nixie Clock Kit
Gas filled nixie tubes with their distinctive orange glow. HH:MM display, automatic power sync 50/60Hz
Power: 9-12Vac 300mA
K8099 Velleman kit £64.96

Mini USB Interface Board
New from Velleman this little interface module with 15 inputs/outputs inc digital & analogue in, PWM outputs. USB Powered 50mA, Software supplied
VM167 Module £26.80

Thermostat Mini Kit
General purpose low cost thermostat kit. +5 to +30°C Easily modified temperature range/min/max/hysteresis 3A Relay
Power: 12Vdc 100mA
MK138 Velleman Kit £4.55

Velleman Function Generator
PC Based USB controlled function generator. 0.01Hz to 2Mhz Predefined & waveform editor. Software supplied. See web site for full feature list.
PCGU1000 Velleman £118.38

Velleman PC Scope
PC Based USB controlled 2 channel 60Mhz oscilloscope with spectrum analyser & Transient recorder. 2 Scope probes & software included. See web site for full feature list.
PCSU1000 Velleman £249.00

Velleman PC Scope/Generator
PC Based USB controlled 2 channel oscilloscope AND Function generator. Software included. See web site for full feature list.
PCSGU250 Velleman £113.67

RF Remote Control Transmitter
Single channel RF keyfob transmitter with over 13,122 combinations. Certified radio frequency 433.92MHz.
Power: 12Vdc 2mA (inc) For use with TL-1,2,3,4 receivers.
TL-5 Cebek Module £14.64

RF Remote Control Receiver
Single channel RF receiver with relay output. Auto or manual code setup. Momentary output, 3A relay
Power: 12Vdc 60mA For use with TL-5 or TL-6 transmitters.
TL-1 Cebek Module £28.25

Keypad Access Control
An electronic lock with up to ten 4 digit codes. Momentary or timed (1-60ec/1-60min) output. Relay 5A
Power: 12Vdc 100mA Keypad included.
DA-03 Cebek Module £54.26

AC Motor Controller
A 230Vac 375W motor speed control unit giving 33 to 98% of full power.
Power: 230Vac
R-8 Cebek Module £12.14

Digital Record/Player
Non volatile flash memory, Single 20 sec recording via integral mic, 2W output to 8Ω speaker.
Power: 5Vdc 100mA
C-9701 Cebek Module £7.89

2 Digital Counter
Standard counter, 0 to 99 from input pulses or external signal. With reset input, 13.5mm Displays, Power: 12Vdc 90mA.
CD-9 Cebek Module £12.99

1.8W Mono Amplifier
Compact mono 1.8W RMS 4Ω power stage, short circuit & reverse polarity protection. 30-18kHz, Power: 4-14Vdc 150mA
E-1 Cebek Module £5.87

20W 2 Channel Amplifier
Mono amplifier with 2 channels (Low & High frequecy), 20W RMS 4Ω per channel, adjustable high level. 22-22kHz, short circuit & reverse polarity protection.
Power: 8-18Vdc 2A
E-14 Cebek Module £22.11

5W Stereo Amplifier
Stereo power stage with 5W RMS 4Ω, 30-18kHz, short circuit & reverse polarity protection.
Power: 6-15Vdc 500mA
ES-2 Cebek Module £21.54

12Vdc Power Supply
Single rail regulated power supply complete with transformer. 130mA max, low ripple, 12Vdc with adjustment.
FE-103 Cebek Module £13.16

1-180 Second Timer
Universal timer with relay output. Time start upon power up or push button. LED indication. 5A Relay
Power: 12Vdc 60mA
I-1 Cebek Module £12.92

Cyclic Timer
Universal timer with relay output. Time start upon power up or push button. On & Off times 0.3-60 Seconds, LED indication. 5A Relay
Power: 12Vdc 80mA
I-10 Cebek Module £14.12

Light Detector
Adjustable light sensor operating a relay. Remote sensor & terminals for remote adjustment pot. 5A Relay
Power: 12Vdc 60mA
I-4 Cebek Module £13.98

Liquid Level Detector
A liquid level operated relay. Remote sensor operates relay when in contact with a liquid. 5A Relay
Power: 12Vdc 60mA
I-6 Cebek Module £13.08

Thermostat
A temerature controlled relay. Adjustable between -10 to 60°C Sensor on remote PCB. Connector for external adjustment pot. 5A Relay
Power: 12Vdc 60mA
I-8 Cebek Module £12.80

Start / Stop Relay
Simple push button control of a relay. Either 1 or 2 button operation 5A Relay
Power: 12Vdc 60mA
I-9 Cebek Module £12.83

Components | Hardware | Soldering | Switches | Test Equipment | Transformers | Motors
PCB Equipment | Connectors | Power Supplies | Enclosures | Relays

ESR ELECTRONIC COMPONENTS
www.esr.co.uk

07/11

Tel: 0191 2514363
Fax: 0191 2522296
sales@esr.co.uk

Station Road
Cullercoats
Tyne & Wear
NE30 4PQ

Prices Exclude Vat @20%.
UK Carriage £2.50 (less than 1kg)
£6.50 greater than 1kg or >£30
Cheques / Postal orders payable to
ESR Electronic Components Ltd.
PLEASE ADD CARRIAGE & VAT TO ALL ORDERS

VOL. 41 No. 7 JULY 2012

Editorial Offices:
EVERYDAY PRACTICAL ELECTRONICS
EDITORIAL Wimborne Publishing Ltd., 113 Lynwood Drive, Merley, Wimborne, Dorset, BH21 1UU
Phone: (01202) 880299. **Fax:** (01202) 843233.
Email: enquiries@wimborne.co.uk
Website: www.epemag.com
See notes on **Readers' Technical Enquiries** below – we regret technical enquiries cannot be answered over the telephone.

Advertisement Offices:
Everyday Practical Electronics Advertisements
113 Lynwood Drive, Merley, Wimborne, Dorset, BH21 1UU
Phone: 01202 880299 **Fax:** 01202 843233
Email: stewart.kearn@wimborne.co.uk

Editor:	MATT PULZER
Consulting Editor:	DAVID BARRINGTON
Subscriptions:	MARILYN GOLDBERG
General Manager:	FAY KEARN
Graphic Design:	RYAN HAWKINS
Editorial/Admin:	(01202) 880299
Advertising and Business Manager:	STEWART KEARN (01202) 880299
On-line Editor:	ALAN WINSTANLEY
EPE Online (Internet version) **Editors:**	CLIVE (Max) MAXFIELD and ALVIN BROWN
Publisher:	MIKE KENWARD

READERS' TECHNICAL ENQUIRIES
Email: techdept@wimborne.co.uk
We are unable to offer any advice on the use, purchase, repair or modification of commercial equipment or the incorporation or modification of designs published in the magazine. We regret that we cannot provide data or answer queries on articles or projects that are more than five years' old. Letters requiring a personal reply must be accompanied by a stamped self-addressed envelope or a self-addressed envelope and international reply coupons. We are not able to answer technical queries on the phone.

PROJECTS AND CIRCUITS
All reasonable precautions are taken to ensure that the advice and data given to readers is reliable. We cannot, however, guarantee it and we cannot accept legal responsibility for it.

A number of projects and circuits published in EPE employ voltages that can be lethal. You should not build, test, modify or renovate any item of mains-powered equipment unless you fully understand the safety aspects involved and you use an RCD adaptor.

COMPONENT SUPPLIES
We do not supply electronic components or kits for building the projects featured, these can be supplied by advertisers.

We advise readers to check that all parts are still available before commencing any project in a back-dated issue.

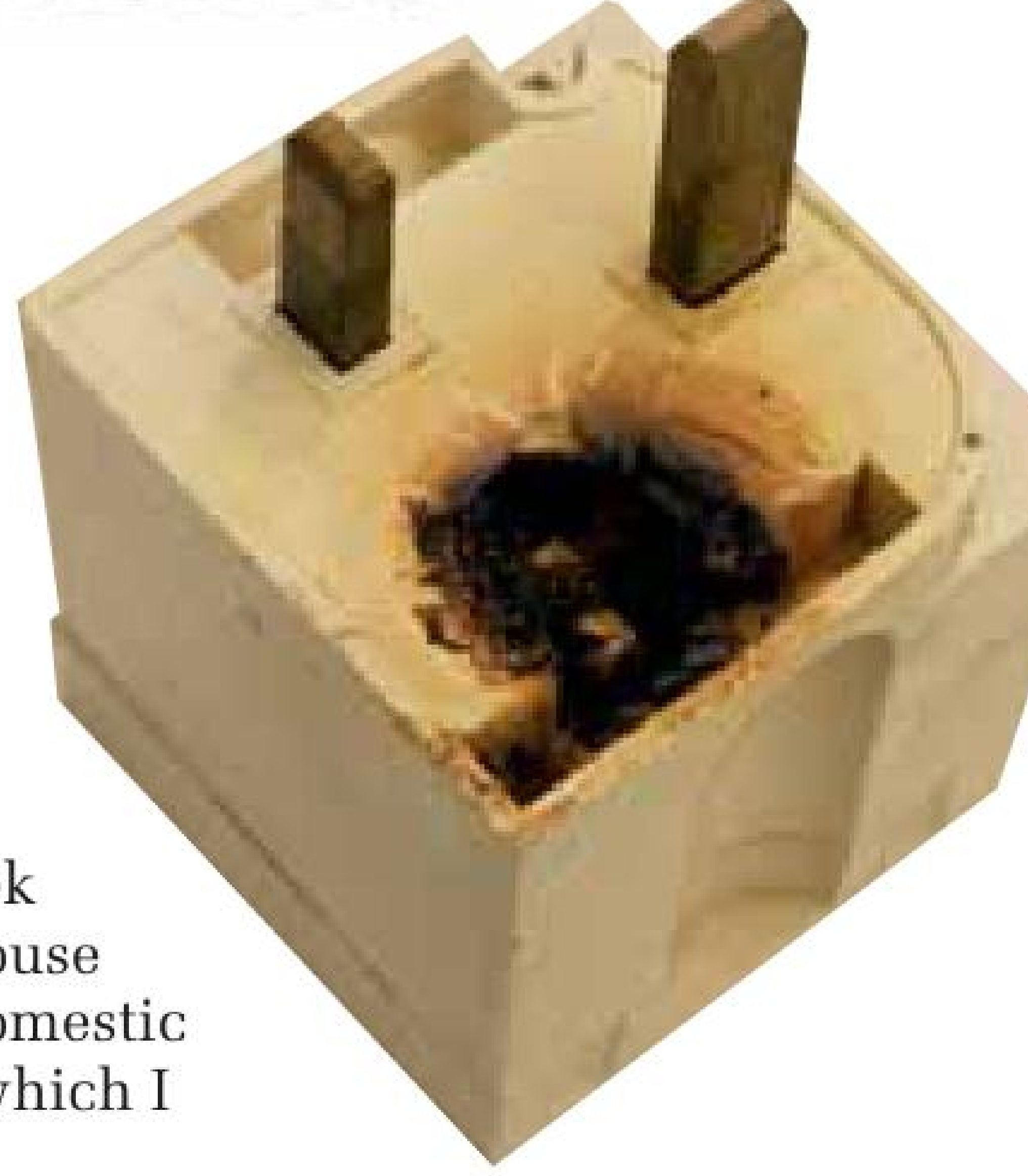
ADVERTISEMENTS
Although the proprietors and staff of EVERYDAY PRACTICAL ELECTRONICS take reasonable precautions to protect the interests of readers by ensuring as far as practicable that advertisements are bona fide, the magazine and its publishers cannot give any undertakings in respect of statements or claims made by advertisers, whether these advertisements are printed as part of the magazine, or in inserts.

The Publishers regret that under no circumstances will the magazine accept liability for non-receipt of goods ordered, or for late delivery, or for faults in manufacture.

TRANSMITTERS/BUGS/TELEPHONE EQUIPMENT
We advise readers that certain items of radio transmitting and telephone equipment which may be advertised in our pages cannot be legally used in the UK. Readers should check the law before buying any transmitting or telephone equipment, as a fine, confiscation of equipment and/or imprisonment can result from illegal use or ownership. The laws vary from country to country; readers should check local laws.

EPE EVERYDAY PRACTICAL ELECTRONICS

Don't let electrical familiarity breed contempt



We try hard to encourage all readers – novices and old hands – to practise electronics in a safe and responsible manner. You may feel that sometimes we overdo the safety warnings scattered around *EPE* projects, but it really is better to be 'safe than sorry'.

This was brought home to me last week when I discovered a problem in my house wiring – in fact, the very part of the domestic supply that powers the computer on which I work on *EPE*.

The computer and all its assorted peripherals run off a single socket and assorted multi-socket extensions. It is – of course – a 'rat's nest' of cables under the desk, but I never really worried, the actual load is not high, easily within the 13A rating of a single plug. In fact, the system runs happily off an extension cable with a built-in 6A thermal cut out, so it really shouldn't present much of a burden to my domestic distribution system.

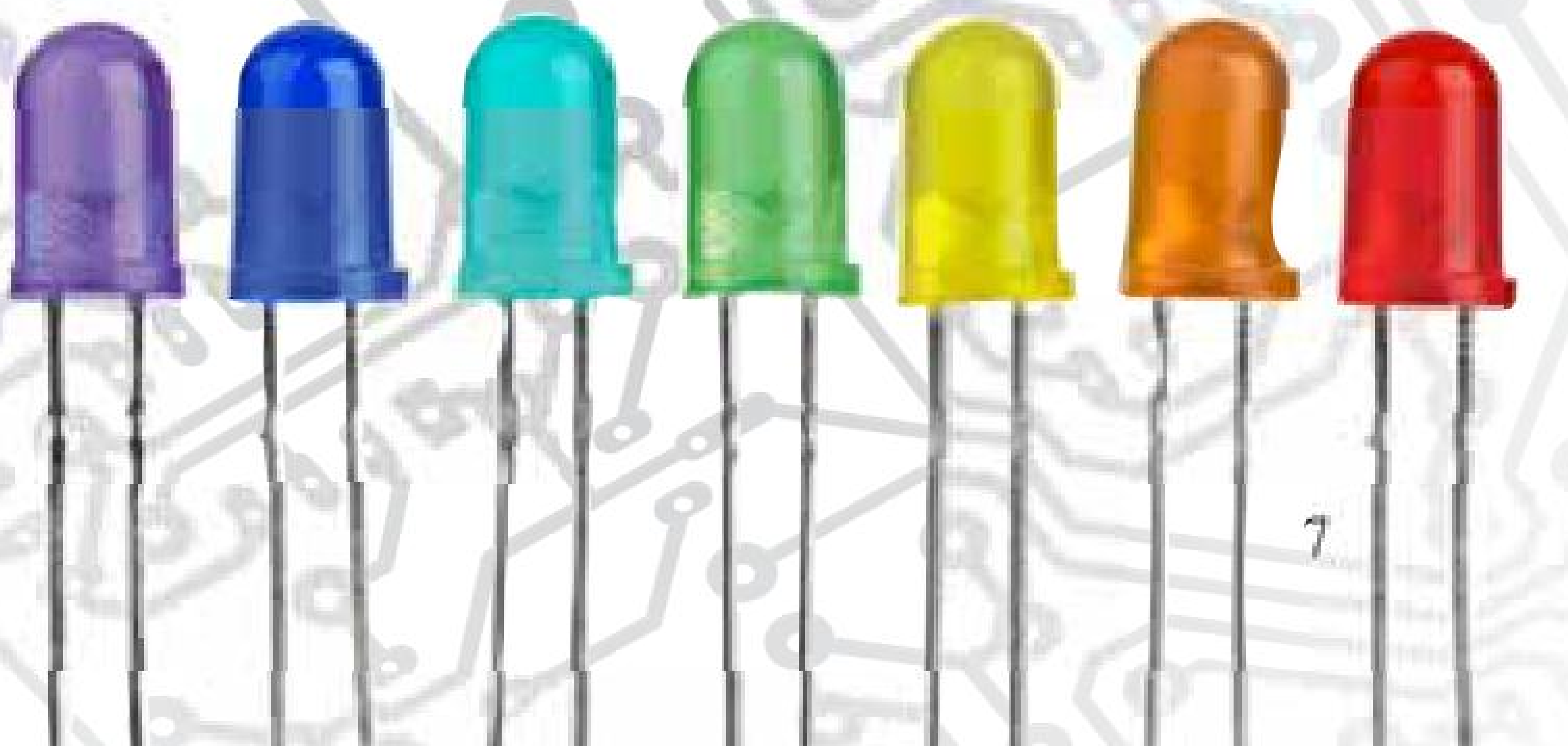
While I was correct in assuming my computer wasn't presenting much of a load, I was working on the assumption that the supply had been correctly installed. However, it seems the wall socket wasn't wired up very well and the ring main neutral cable was really only touching its retaining clamp. The result was a much higher than expected contact resistance that got very hot when just a few amps passed through the circuit. It got so hot that the heat transferred to the multi-socket plugged into the wall socket melted its plastic, and when I pulled it out, the neutral pin got detached and stayed in the socket, revealing a nasty heat-blackened mess of burnt plastic.

It could have caused a fire at any time – perhaps when I wasn't around to put it out, or worse still, when I was asleep.

There are two lessons here. The first – never assume a system is safe unless you know it has been installed safely. If, like me, you live in an old house, where the wiring has grown incrementally, you could do a lot worse than get it checked out by a competent electrician. He or she will know what to test for, and have the experience and equipment to do it properly.

Lesson number two? – you may be saying to yourself, 'yes, a fire is awful, but surely you have a fire detector system?'. Well, yes I do, there is a heat detector in the kitchen and a high quality smoke detector just above where my dodgy socket sits. Unfortunately, because I was having very dusty building work carried out in the house it was neatly sealed with a plastic bag. It seemed like a smart idea at the time – it wasn't, quite the opposite.

I've been pretty lucky, one loose wire at exactly the wrong time could have been disastrous, even fatal – please learn from my mistakes.



NEWS

A roundup of the latest Everyday News from the world of electronics

Water-repelling electronics by Barry Fox

A water droplet sitting on an Aridion-coated 'fluffy' surface will not be absorbed

Water and electricity don't mix. Even if there is no shock risk, a short dip will be enough to let capillary action suck liquid into nooks and crannies between components on a circuit board, where it progressively corrodes. No amount of shaking and drying will get it all out, which is why manufacturers and reputable service centres usually refuse even to try and repair any equipment with water damage. They know more faults will develop later. (iPhones, for example, have built-in water sensors that change permanently if they take a 'dunk'.)

Call for Aridion

Now, however, there is an impressive solution to the problem; a water-repellent coating called Aridion. But will manufacturers use it and cut off the valuable revenue stream from replacement sales?

Those who use Aridion seem curiously coy, perhaps because they fear customers will regard 'water-repellent' as 'waterproof'', which it is not.

Aridion comes from UK company P2i. It is already used in hearing aids and by Motorola, under the brand name Splashguard, for new Razr cellphones and tablets. 'We did not send out any press information specifically on that feature', says a spokeswoman for Motorola.

'Hearing aids are especially vulnerable to water damage' company founder Dr Stephen Coulson told me at a small exhibition of new CE products during a recent preview event for the *IFA Berlin* show. 'They use zinc-air batteries, which need air to function, so the casings cannot be sealed and waterproofed. And they get wet in everyday use. Our coating is three-times more water-repellent than Teflon. Four of the five largest hearing aid manufacturers are now using Aridion, and they have treated over six million units since 2009.

Demonstration

Coulson then gave an impressive demonstration using treated and untreated Samsung smartphones; when water is poured onto the treated circuit board it gathers into near-spherical balls instead of spreading and creeping.

The Aridion coating also stops touch screens showing fingermarks, prevents staining and keeps clothes clean. So it could replace those plastic film screen covers, which are so hard to apply cleanly.

Stephen Coulson invented Aridion while studying for a doctorate at Durham University. He found a fluorinated acrylate chemical compound that has the unique properties of repelling liquids such as oil and water, but also bonding tightly to solid surfaces.

Commercially, the material is applied as ionised gas plasma in a vacuum chamber. Because the chemical particles are very small, only a few nanometres in size, there is no need to open the devices; the coating material is sucked inside any casing and deposits on to metal or plastics as an invisible layer around one thousandth the thickness of a human hair. The process works at low temperature so does not harm microchips. But it cannot be used with devices that do not withstand low pressures.

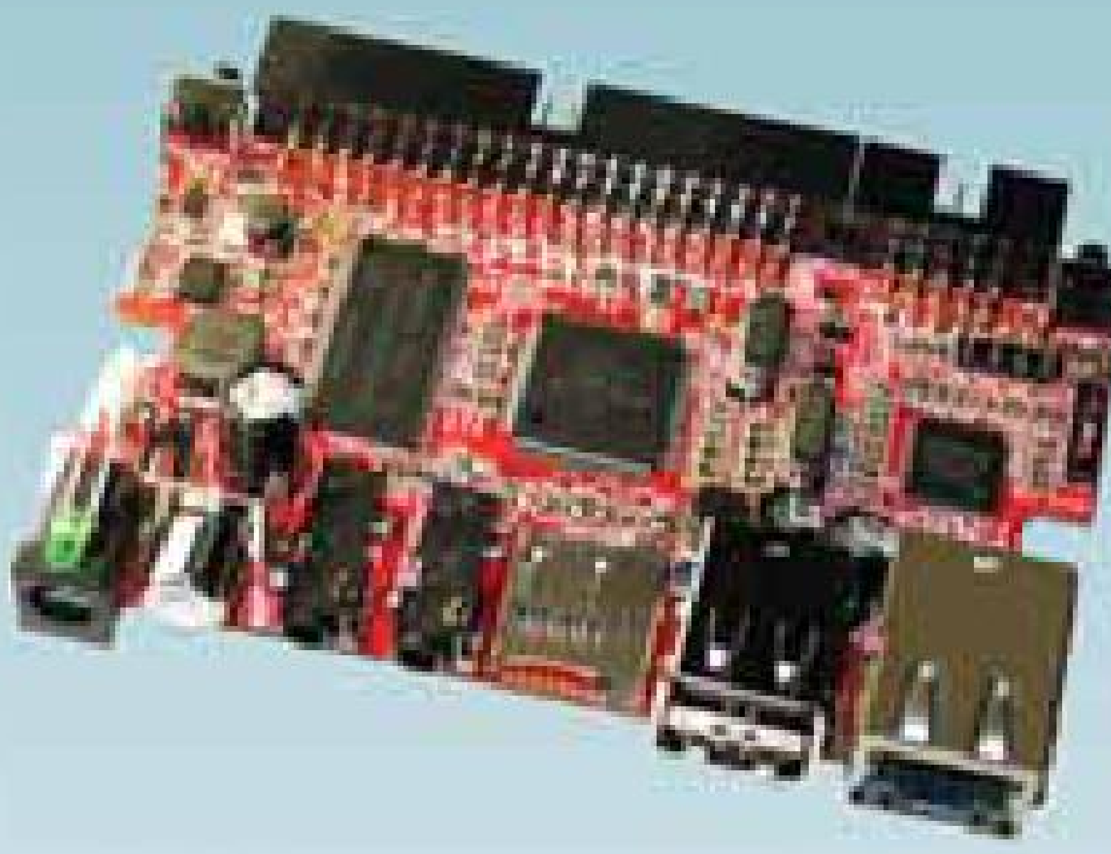
Factories, such as Motorola's in China, install cabinet chambers after the main production line. One cabinet can treat 100,000 phones a day, in batches of a thousand, loaded hourly by unskilled workers.

Keeping PCBs 'dry' could save many devices from a wet grave

Coulson explains the business model; the UK government's MoD (Ministry of Defence) owns the intellectual property, including many patents, and P2i has a sole licence to use this IP. P2i installs the treatment chambers and charges a royalty per device treated. The charge is low enough for the manufacturer to absorb it, claims Coulson. 'So the consumer does not see the cost, just the benefit when they drop their phone in the bath tub or down the toilet'.

More Pi anyone?

By Mike Hibbert



The ARM9-based OLinuXino board

Olimex, the Bulgarian PCB manufacturer and supplier of microcontroller development boards has entered the Raspberry Pi market with its own ARM-based product. The OLinuXino provides composite video output in PAL or NTSC format, two USB host interfaces for keyboard, mouse or other peripherals, and has network connectivity through a 100MB/s Ethernet interface. Processing power comes from a Freescale iMX233 454MHz ARM9 processor and 64MB of RAM. A MicroSD card provides the OS, application and data storage.

While not as powerful as the Raspberry Pi, the board has been designed with hobbyists in mind, with further I/O available through a 2 × 20 0.1-inch pitch header and an additional 2 × 5 header configured to Olimex's UEXT interface standard. The board format has been specifically designed to fit a standard off-the-shelf, low-cost plastic enclosure. The board includes a lithium polymer battery charger, enabling portable, battery-powered applications.

Unlike the Raspberry Pi, OLinuXino's hardware and firmware is fully open source, and the components have been selected to enable enthusiasts to design and build their own boards. The iMX233 processor is a complex multimedia applications device with full memory management capability and on-chip multimedia functions, enabling it to control a high-resolution colour LCD display fitted with a multi-touch sensor.

The initial operating software will be based on the standard Linux Kernel that is being enthusiastically ported to the board by an international group of hobbyists and engineers. All networking, file system and multimedia capability will be provided through the use of Linux and the GNU suite of free software.

The OLinuXino will be produced in two versions (with and without an Ethernet interface) with prices starting at 30 euro. Olimex's owner, Tsvetan Usunov claims, 'the board will be a bridge to the Linux development community for the Duinomite/Arduino/Maple/Pinguino world of developers.' Production was scheduled to start in May.

Visit Olimex's website for further details: ***www.olimex.com/dev***

Memristor technology breakthrough

Long promised, but never realised in a commercial technology, it now looks as though researchers at University College London (UCL) have made a breakthrough in 'memristor' technology.

A memristor is a resistor with memory; although the UCL team prefer the name resistive RAM – or RRAM. Such a device can switch between one or more resistances under the application of appropriate voltages. Devices can have two (or more) discrete resistance states, or may have a continuously variable resistance. Whatever the case, it is important that the change in resistance is governed by the past history of the device – that is, by the previous voltage applied, or the previous current that has flowed through the device.

Microelectronic designers find RRAMs attractive because they can be packed much more densely, fabricated in 3D arrays, have very low switching energies and fast switching speeds. Also, devices whose state depends on their past history behave in some ways similarly to neurons – RRAMs can thus be used to fabricate very high density neural networks.

However, despite memristor technology's theoretical promise and obvious advantages, the problem has been how to make them. Most working designs have needed difficult-to-make or expensive materials, severely limiting their potential to be the 'next Flash memory' of choice.

This is where the UCL design look so promising. The London team has developed, and filed a patent on, an RRAM device based wholly on the conventional Si/SiO$_2$ system. In other words, it can be fabricated only from *n*- and *p*- type silicon and silicon oxide, operating in ambient conditions.

Their devices show a resistance contrast of up to five orders of magnitude, switching time is 90ns or shorter, and switching energy is 1pJ/bit or lower. Initial studies show that the individual switching elements may be made as small as 10nm.

Engineering site of the day

Alan Winstanley's EPEmag.net website

It's nice to be praised, and I hope our readers will excuse a little promotion for Alan Winstanley's (our on-line editor) personal website! EPEmag.net was highlighted as 'Engineering Site of the Day' on **www.eeweb.com** on 4 April. High praise indeed – and fully deserved – what's more, apparently Alan will be 'Engineer of the Day' in June. See: **www.eeweb.com/websites/epemag.net**

Minibot launch

The latest robot kit from SparkFun

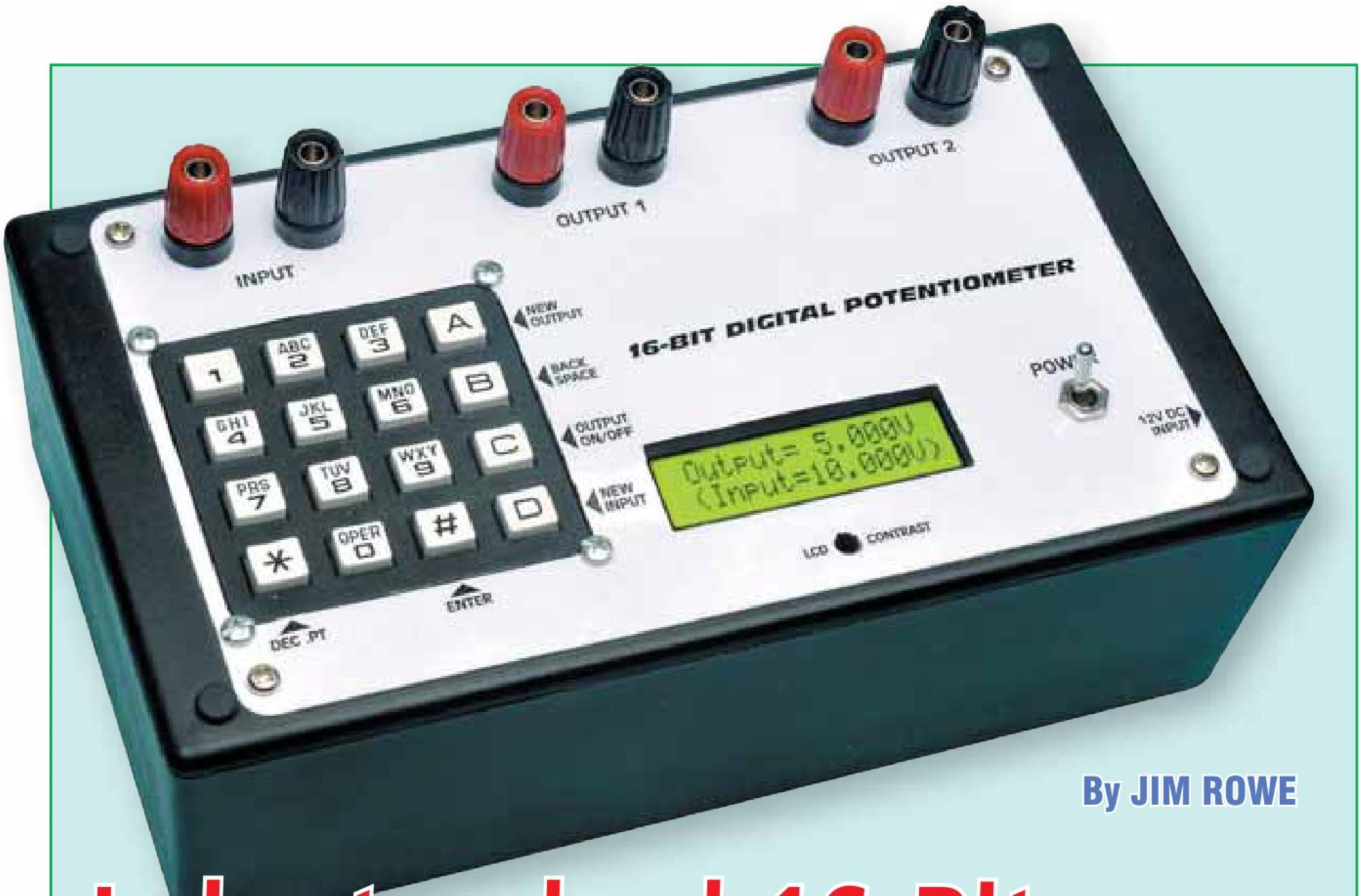
SparkFun Electroncs is releasing a new kit designed to help people learn about robotics. The kit provides a way to explore all kinds of concepts like navigation, obstacle detection, handling sensor data, as well as real-world physical computing problems.

The ProtoSnap MiniBot is a robot platform that is Arduino-compatible and customisable. It should also be a lot of fun to play with. More details are at: ***www.sparkfun.com***

Tidal power starts to flow

An underwater turbine, that is set to be used in Scotland's first tidal power project, has successfully completed an initial testing period in Orkney, and is providing electricity for homes and businesses on the island of Eday, one of Orkney's northern isles.

The 1MW power generator was installed last December, in some of the worst weather conditions Scotland has experienced in more than a decade, and has since been undergoing a range of tests in the fast flowing tidal waters around the island group.



By JIM ROWE

Lab-standard 16-Bit Digital Potentiometer

No, this is not some kind of fancy digital volume control for hifi systems. Instead, it's a low-cost digital 'programmable' voltage divider. It's used to provide an accurate adjustable output from a precision voltage reference for meter calibration and other tasks.

LET'S SAY you've built the *Precision DC Voltage Reference* described in the June 2011 issue of *EPE*. This provides an accurate 10.000V DC voltage source, which is fine for calibrating the higher voltage ranges of a DMM or other meter. But how can you use it for calibrating the lower ranges? That's when you need to use a voltage divider, to break down the 10.000V to a suitable lower level – like 4.999V, 1.999V or even 199.9mV.

In principle, a voltage divider is very straightforward; however, in this situation, there's a special requirement: the divider's division ratio should be programmable with a high degree of accuracy, if the accuracy of its output is not to be degraded significantly from that of the 10.000V reference.

So that's the idea behind this new *Digital Potentiometer*; it's designed to provide a voltage divider with an accurately programmable division ratio over a 10,000:1 range. It will allow you to take the 10.000V reference and derive any lower voltage you wish – from 0.001V (1mV) up to 9.999V – with a resolution of 1mV and an absolute accuracy of ±0.2mV up to 200mV, ±0.5mV up to 1.000V and ±1mV up to 9.999V.

These figures translate to a relative accuracy of ±0.4% at 10mV, ±0.02% at 100mV, ±0.05% at 1V and ±0.01% at 9.9V. This order of accuracy should be quite suitable for calibrating the majority of handheld DMMs and similar instruments.

Because the potentiometer itself uses purely resistive elements, it can be used as an accurate divider for

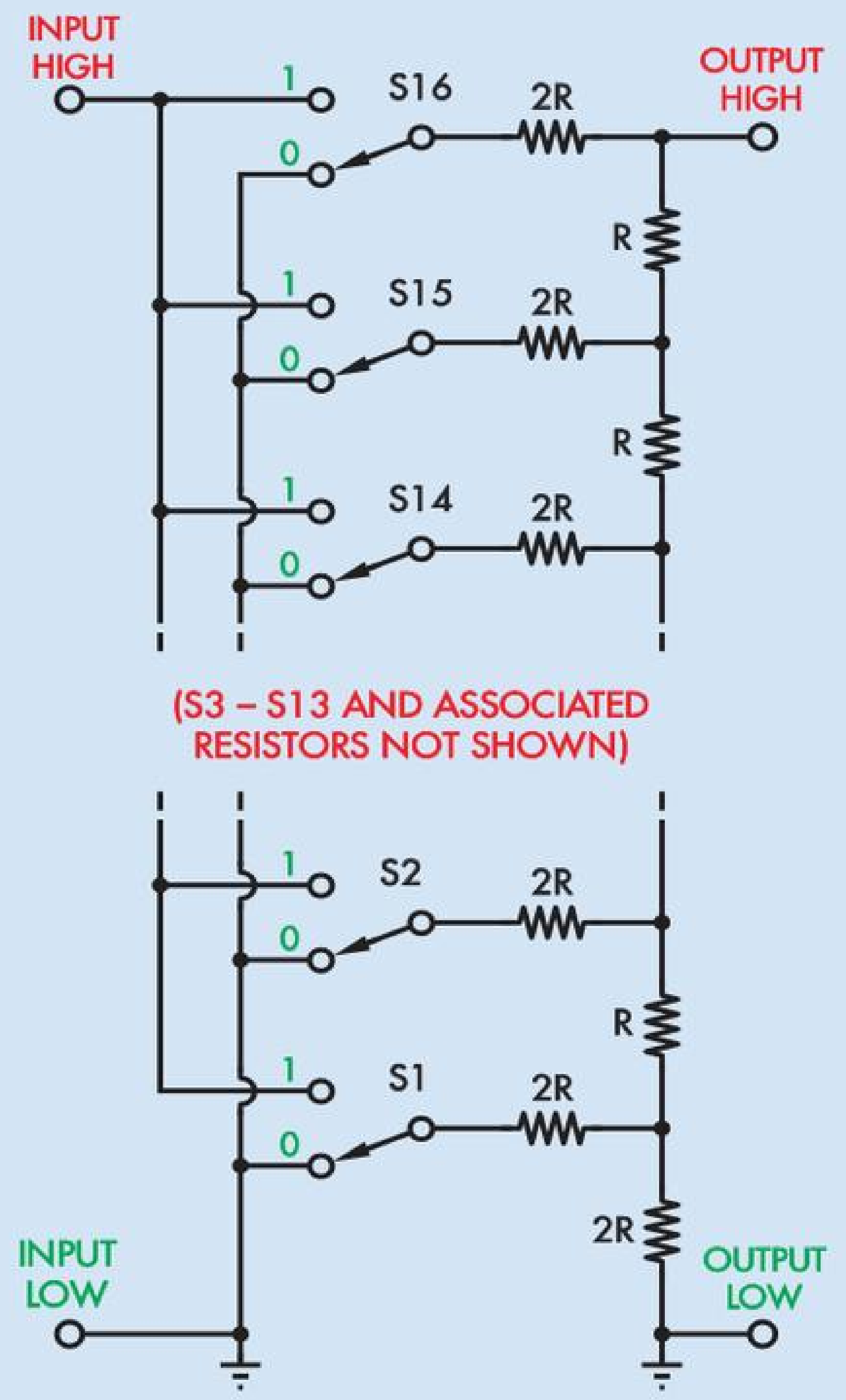


Fig.1: the basic form of the 16-step R/2R ladder network (switches S3 to S13 omitted for clarity).

low-frequency AC (eg, below 20kHz) as well as DC.

How it works

In order to achieve this level of accuracy and to make the *Digital Potentiometer* easily programmable, we have adopted the same 'binary-switched resistive ladder' configuration used in many linear DACs (digital-to-analogue converters). We have used a 16-step ladder because this allows the division ratio to be adjusted in 65,536 discrete steps. That's because $2^{16} = 65{,}536$, meaning that 16 binary switches have the potential for 65,536 different combinations (0 to 65,535 inclusive).

The basic form of the 16-step ladder is shown in Fig.1, although only five of the 16 switches are shown; ie, the two lowest switches S1 and S2, and the three uppermost switches S14 to S16. The intermediate switches (S3 to S13) have been omitted for clarity.

This configuration may not look like a conventional voltage divider, but it does the same job and has the advantage that the binary 'weighting' of each switch increases by a factor of two, as you move up from S1 to S2, S2 to S3 and so on up to S16. So the divider's output (as a proportion of the input) can be programmed very simply in binary fashion.

Switch S1 has a binary weighting of 1, S2 a weighting of 2, S3 a weighting of 4 and so on all the way up to S16, which has a weighting of 32,768. If we connect this 16-step divider to an input voltage of 10.000V, it is, therefore, capable of providing an output voltage adjustable in steps of 0.15259mV (10,000/65,535) from 0V to 10.000V, simply by setting switches S1 to S16 to the correct binary combination.

So, the simple switched resistive ladder arrangement of Fig.1 is quite capable of being used as a precision voltage divider as it stands. But in this simple binary form it would be difficult to program; you'd have to work out the binary number corresponding to the particular output voltage you wanted, in order to set the 16 switches.

Instead, we have used a PIC microcontroller to drive a set of 16 SPDT relays in place of the switches, as shown in the block diagram of Fig.2. This allows you to simply key in the output voltage you want (in decimal) via a keypad, with an LCD readout to show you what you're doing. The micro (IC1) calculates the correct binary number to program the divider's 16 relays to achieve this output voltage – or as close as it can get.

Resolution and accuracy

Before we look at the full circuit of the *Digital Potentiometer*, we should clarify a few points regarding its accuracy. There are two main factors which determine the unit's accuracy: (1) the resolution of the binary ladder as a whole by virtue of it having 16 steps, and (2) the accuracy of the binary weighting of each of those individual steps as a function of the tolerance of the 'R' and '2R' resistors in the ladder.

As mentioned, the basic resolution of a 16-bit binary divider is 1/65,535. So, in this situation, where it is dividing down from an input voltage of 10.000V, the resolution becomes 0.15259mV per binary step. This means that even if all the resistors in the ladder network have values of exactly R and 2R as required, we will only be able to program any particular output voltage to an accuracy of ±0.076295mV (ie, 0.15259/2).

Let's say, we want to program the divider for an output voltage of

Parts List

1 PC board, code 856, available from the *EPE PCB Service*, size 184mm × 99.5mm
1 UB2-size plastic box, 197mm × 113mm × 63mm
1 16 × 2 LCD module, Altronics Z-7013 or similar (with LED backlighting)
1 16-key (4 × 4 matrix) keypad
16 SPDT mini DIL relay, 6V coil
1 SPDT mini toggle switch (S1)
1 4MHz crystal (X1)
1 2.5mm concentric power connector, PC board mtg (CON1)
1 40-pin 0.6-inch DIL IC socket
1 16-way SIL socket strip
1 16-way SIL pin strip
1 8-way SIL socket strip
1 8-way SIL pin strip (long)
4 M3 × 25mm tapped spacers
2 M3 × 15mm tapped nylon spacers
13 M3 × 6mm screws, pan-head
1 M3 nut
4 No.5 × 8mm self-tapping screws
3 binding post/banana jacks, red
3 binding post/banana jacks, black
1 400mm length of tinned copper wire, 0.7mm diameter
1 10kΩ mini horiz. trimpot, (VR1)

Semiconductors

1 PIC16F877A-I/P programmed microcontroller (IC1)
1 LM7805 +5V regulator (REG1)
16 PN100 *NPN* transistors (Q1-Q16)
17 1N4004 1A diodes (D1 to D17)

Capacitors

1 470µF 16V radial elect.
1 220µF 16V radial elect.
2 100nF monolithic
1 100nF MKT metallised polyester
2 27pF disc ceramic

Resistors (0.25W, 1%)

4 10kΩ
1 8.2kΩ
16 4.7kΩ
1 2.2kΩ
16 47Ω
1 22Ω

Precision resistors

17 3.000kΩ 0.1% metal film (Farnell 1634061)
15 1.500kΩ 0.1% metal film (Farnell 9500901 or 1751462; RS 165-933)

Software

All software program files for the *16-Bit Digital Potentiometer* will be available from the *EPE* website at **www.epemag.com**.

WE DO NOT SUPPLY READY-ROGRAMMED MICROCONTROLLERS

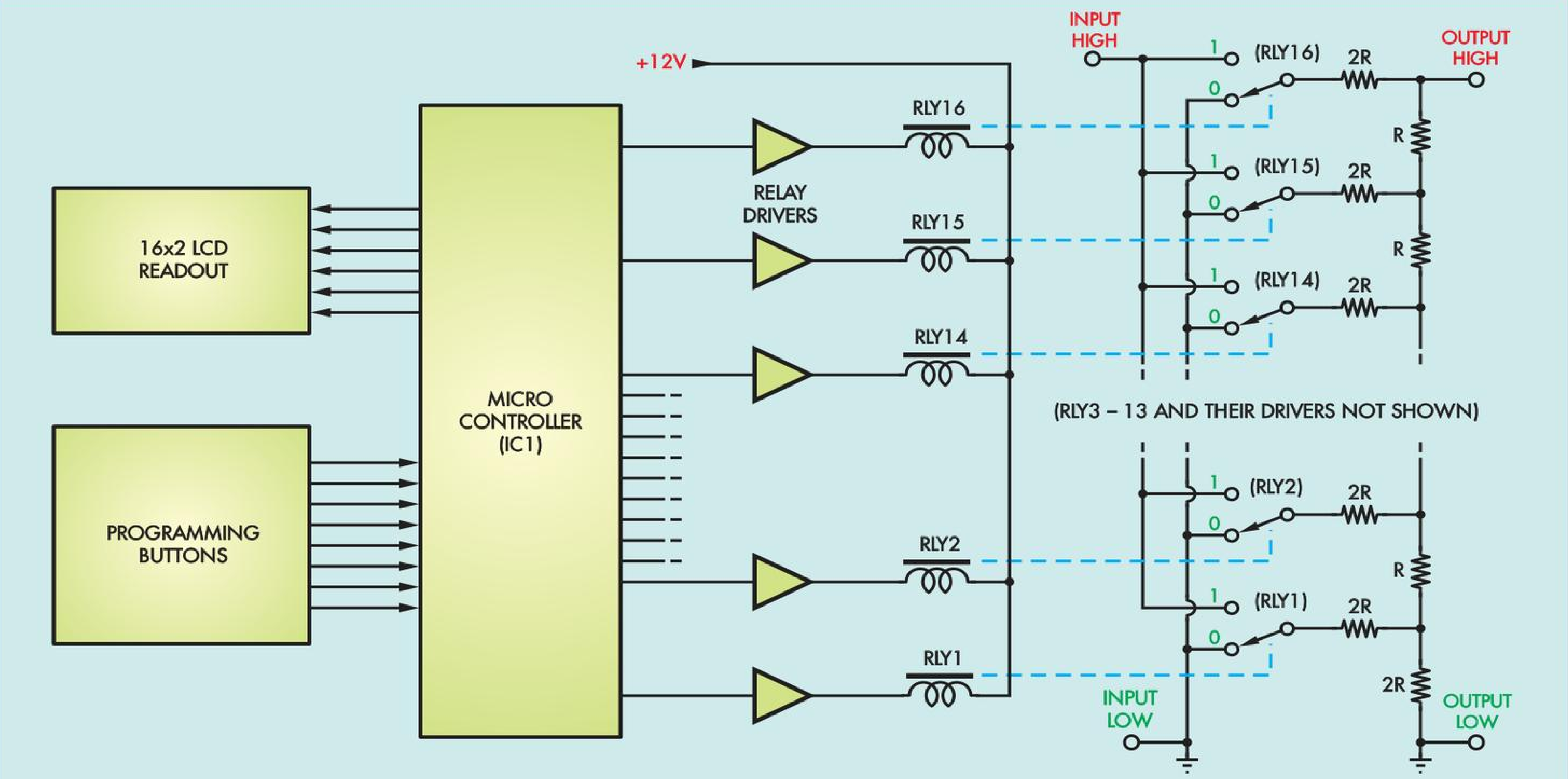


Fig.2: block diagram of the *16-Bit Digital Potentiometer*. The desired output voltage is entered via a keypad and the microcontroller (IC1) calculates the correct binary number to drive the 16 relays in the R/2R ladder network.

0.001V or 1mV. If we do the maths, 1.000/0.15259 = 6.5535. Since we can only program the divider in binary integers, this means that we can only program it for the binary equivalent of either 6 or 7. So our actual output voltage will be either 0.91554mV (6 × 0.15259) or 1.068mV (7 × 0.152159).

This 'resolution error' varies depending on the output voltage setting. For example, if you want to program the divider for a voltage of 3.052V, the binary equivalent of 20,001 will give an actual output voltage of 3.05195V – only 0.05mV low.

On the other hand, if you want an output voltage of 1.000V, the binary equivalent of 6553 will give an output voltage of 999.92mV (0.08mV low) while the equivalent of 6554 will give an output voltage of 1000.075mV (0.075mV high).

So, the actual size and polarity of the divider's resolution error does vary, but should always be within the range of ±0.0763mV. We could only get a lower figure for this error factor by using additional binary divider steps (it will halve for each additional step).

As you can see though, the errors caused by the divider's 16-bit resolution are really not all that great. In terms of relative error, even a 1mV output voltage will only be either high or low by about 7% – and this relative error drops rapidly as the output voltage rises. The relative error for a 50mV output voltage is only +0.099%, while that for a 100mV output voltage is –0.053%.

In practical terms, the second error factor is more serious, because the operation of this type of binary-switched voltage divider does depend on the resistors in each divider step having an exact 2:1 ratio (except for the very bottom step, which must have an exact 2:2 ratio, as shown). This means that this source of error will be zero only with 'perfect' exact-value resistors in all steps. However, with 'real world' resistors, the errors tend to rise significantly, because they accumulate as you move up the ladder.

Main features and specifications

Features

- A lab-type voltage divider, suitable for dividing down the output of a voltage reference to an accurately known lower voltage. It can be used for either DC or AC.
- Desired output voltage is programmed directly in decimal via a keypad, with an LCD readout. The divider output can be disabled or re-enabled at any time, simply by pressing an 'Output Toggle' key.

Specifications

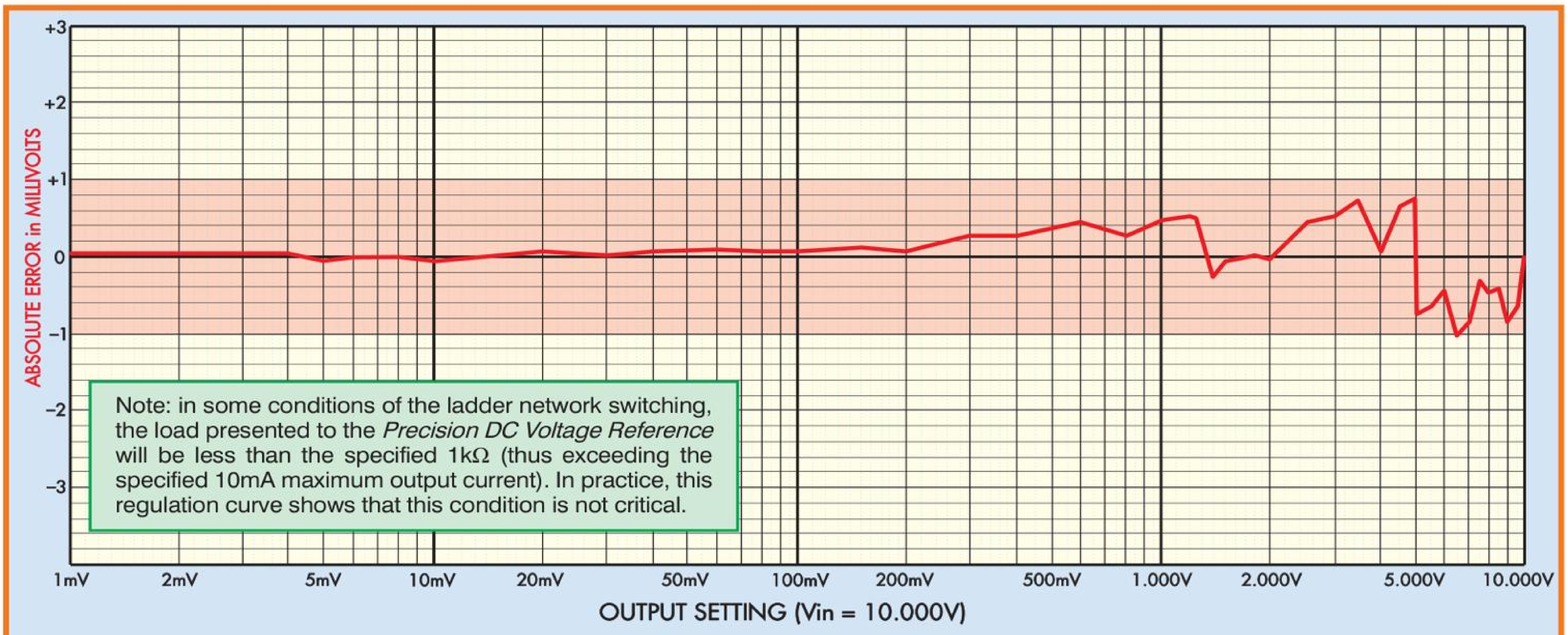
Output resolution: input voltage/65,535 or 0.15259mV steps when V_{in} = 10.000V.

Typical absolute accuracy: see plot in Fig.3. Better than ±1mV over full range, better than ±0.2mV up to 250mV output (V_{in} = 10.000V).

Input resistance: 813Ω minimum

Output resistance: 1.5kΩ (note: do not connect to a load of less than 1.5MΩ in order to obtain the specified accuracy)

Power drain: approximately 4.5W maximum (50mA to 360mA from an external 12V DC supply)



Note: in some conditions of the ladder network switching, the load presented to the *Precision DC Voltage Reference* will be less than the specified 1kΩ (thus exceeding the specified 10mA maximum output current). In practice, this regulation curve shows that this condition is not critical.

Fig.3: this graph plots the absolute error as a function of the output voltage. The absolute error is better than ±0.2mV up to 250mV output, ±0.5mV up to 1V output and ±1mV from 1V up to 10V output.

What does this mean in practice? Well, in our first prototype, we used standard close-tolerance 1% metal film resistors (3.0kΩ and 1.5kΩ) in the ladder, to see what sort of accuracy this would result in (1% resistor values meant that the 2:1 ratio in each of the upper steps, together with the 1:1 ratio for the lowest step, would be only accurate to within ±2%).

However, when we measured the performance of this version, the accuracy was quite poor – particularly for output voltages above 200mV. In fact, the absolute error rose to +1mV at 300mV output, then to +2mV at 1V output, +5mV at 2.500V output, –2.5mV at 2.600V output and 5.1V output, +2.4mV at 7.6V output and –5.5mV at 7.8V output – not good! Clearly, the cumulative effect of the resistor tolerance error was wreaking havoc at the higher outputs.

In view of this poor result, we realised that in order to get acceptable performance, it would be necessary to use ladder resistors with significantly closer tolerance than 1%.

The resistors we finally settled on were of 0.1% tolerance, which result-ed in the absolute error curve shown in Fig.3. This shows that the absolute error is better than ±0.2mV up to 250mV output, ±0.5mV up to 1V output and ±1mV from 1V up to 10V output.

To get any better accuracy than this, you would need to use ladder resistors with closer tolerance again, or else go through the laborious work of selecting a set of 0.1% resistors with closer tolerance from a large stock. That assumes that you have a least one resistor of much higher tolerance to use as your standard.

By the way, even 0.1% tolerance resistors can pose a problem because although the value of 1.500kΩ is available in this tolerance, 3.000kΩ resistors are harder to find. As a result, you may have to use 3.010kΩ resistors, padding each one down to 3.000kΩ (±0.1%) by connecting a 910kΩ 1% resistor in parallel with it.

We should also warn you that 0.1% tolerance metal film resistors are much more expensive than the standard 1% tolerance types: about 35p each. So you'll end up paying about £11.00 for the 32 resistors used in the *Digital Potentiometer's* ladder network.

Circuit description

Now let's look at the full circuit diagram of the *Digital Potentiometer* – see Fig.4. It's not very different from the block diagram of Fig.2 – we've just added the fine details.

The ladder divider is at upper right, with the binary switching done by relays RLY1-RLY16 as before. The relays are mini DIL types and they're all operated from a +11.4V supply rail, with a 47Ω resistor in series with each one to limit the coil current.

Transistors Q1-Q16 are the relay drivers, while diodes D1-D16 are there to protect the transistors from back-EMF damage when each relay is turned off.

Each relay driver transistor is controlled by one of the RB0-7 or RD0-7 port outputs of microcontroller IC1 (PIC16F877A-I/P). The 4.7kΩ base series resistors minimise the loading on the IC's port output lines, while still ensuring that driver transistors Q1-Q16 are switched on and off reliably.

The rest of the circuit is straightforward and is involved mainly with IC1 scanning the 4 × 4 input keypad (at lower left) to detect user input, as well as providing feedback to the user via the 16 × 2 LCD module at lower right.

We have used a 4 x 4 keypad to provide an economical array of 16 input keys – including the 10 keys used to input the numerals 0-9. The additional six keys are used to perform the following functions:

A key: tells the micro that you want to key in a new output voltage.

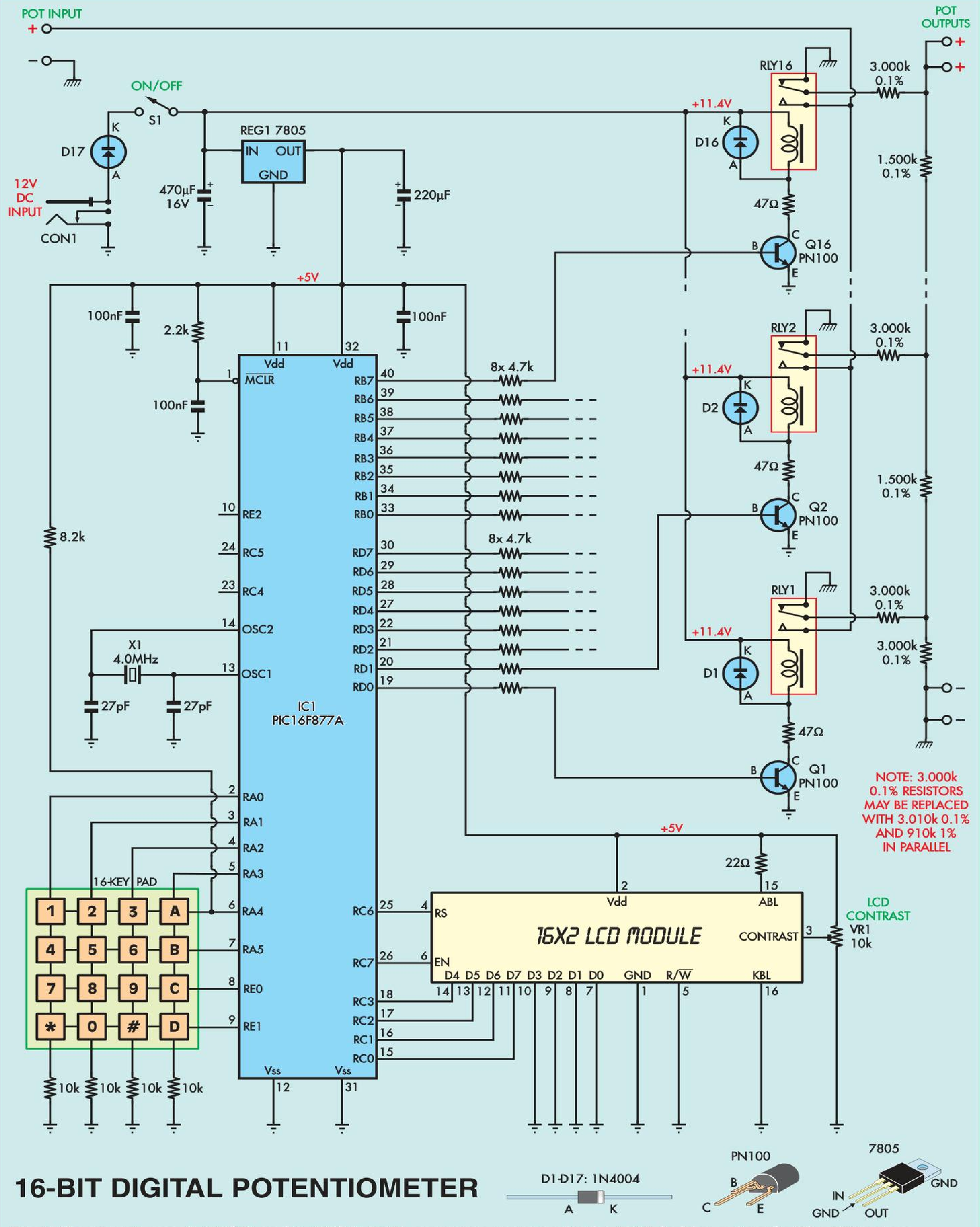
B key: a destructive backspace, for correcting input errors.

C key: toggles the *Digital Potentiometer's* output on/off.

D key: tells the micro that you want to key in a new input reference voltage in place of the default 10.000V.

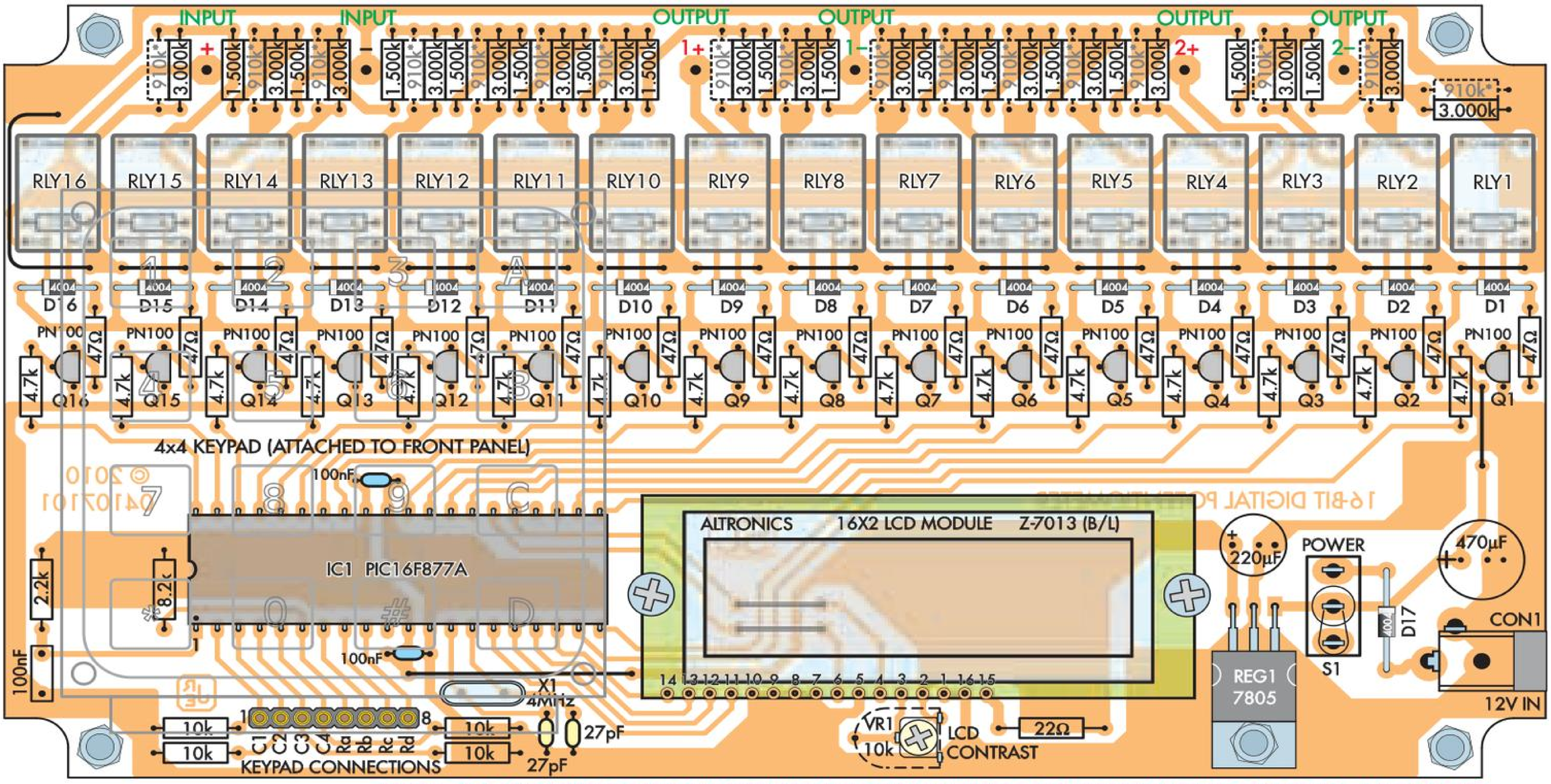
*** key**: acts as the decimal point input key.

# key: acts as the 'Enter' key, to conclude an input entry.


POT INPUT
+
–
ON/OFF
S1
D17
K
A
12V
DC
INPUT
CON1
REG1 7805
IN
OUT
GND
470µF
16V
220µF
+5V
100nF
2.2k
100nF
1
MCLR
11
32
Vdd
Vdd
100nF
8.2k
RB7 40
RB6 39
RB5 38
RB4 37
RB3 36
RB2 35
RB1 34
RB0 33
8x 4.7k
10 RE2
24 RC5
23 RC4
14 OSC2
13 OSC1
X1
4.0MHz
27pF
27pF
RD7 30
RD6 29
RD5 28
RD4 27
RD3 22
RD2 21
RD1 20
RD0 19
8x 4.7k
IC1
PIC16F877A
2 RA0
3 RA1
4 RA2
5 RA3
6 RA4
7 RA5
8 RE0
9 RE1
16-KEY PAD
1 2 3 A
4 5 6 B
7 8 9 C
* 0 # D
10k 10k 10k 10k
Vss 12
Vss 31
RC6 25
RC7 26
RC3 18
RC2 17
RC1 16
RC0 15
+11.4V
RLY16
D16
47Ω
Q16
PN100
B
C
E
RLY2
D2
Q2
PN100
RLY1
D1
Q1
PN100
POT
OUTPUTS
3.000k
0.1%
1.500k
0.1%
3.000k
0.1%
1.500k
0.1%
3.000k
0.1%
3.000k
0.1%
NOTE: 3.000k
0.1% RESISTORS
MAY BE REPLACED
WITH 3.010k 0.1%
AND 910k 1%
IN PARALLEL
+5V
22Ω
16X2 LCD MODULE
2 Vdd
15 ABL
4 RS
6 EN
CONTRAST 3
LCD
CONTRAST
VR1
10k
D4 D5 D6 D7 D3 D2 D1 D0 GND R/W KBL
14 13 12 11 10 9 8 7 1 5 16
D1-D17: 1N4004
A K
PN100
B
C E
7805
GND
IN
GND
OUT

16-BIT DIGITAL POTENTIOMETER

Fig.4: the circuit uses 3.000kΩ and 1.500kΩ 0.1% precision resistors in the R/2R ladder network. The PIC micro calculates the binary value from the entered data and drives relays RLY1 to RLY16 via *NPN* transistors Q1 to Q16.


INPUT
INPUT
OUTPUT
OUTPUT
OUTPUT
OUTPUT
+
−
1+
1−
2+
2−
910k*
3.000k
1.500k
RLY16
RLY15
RLY14
RLY13
RLY12
RLY11
RLY10
RLY9
RLY8
RLY7
RLY6
RLY5
RLY4
RLY3
RLY2
RLY1
4004
D16
D15
D14
D13
D12
D11
D10
D9
D8
D7
D6
D5
D4
D3
D2
D1
PN100
47Ω
4.7k
Q16
Q15
Q14
Q13
Q12
Q11
Q10
Q9
Q8
Q7
Q6
Q5
Q4
Q3
Q2
Q1
4x4 KEYPAD (ATTACHED TO FRONT PANEL)
1
2
3
A
4
5
6
B
7
8
9
C
*
0
#
D
© 2010
04107101
100nF
IC1 PIC16F877A
2.2k
8.2k
100nF
100nF
ALTRONICS 16X2 LCD MODULE Z-7013 (B/L)
16-BIT DIGITAL POTENTIOMETER
X1
4MHz
27pF
27pF
10k
10k
10k
10k
C1 C2 C3 C4 Ra Rb Rc Rd
KEYPAD CONNECTIONS
14 13 12 11 10 9 8 7 6 5 4 3 2 1 16 15
VR1
10k
LCD
CONTRAST
22Ω
220µF
POWER
S1
470µF
D17
CON1
REG1
7805
12V IN

*NOTE: 910k 1% RESISTORS ARE ONLY REQUIRED IF 3.010k 0.1% RESISTORS ARE USED INSTEAD OF 3.000k 0.1% RESISTORS

Fig.5: install the parts on the PC board as shown on this overlay diagram and the photo ooverleaf. Be sure to use 0.1% tolerance resistors as specified in the R/2R ladder network (ie, for the 1.500kΩ and 3.000kΩ types) – see parts list.

The display on the LCD module shows the unit's status in each operating mode. When you are keying in a new output (or input) voltage, it displays the digits as you enter them.

In the normal mode, where the divider is set to provide a specific output voltage, it displays that voltage along with the assumed input voltage. Or, if you have toggled the divider's output off, it displays 'OFF' to remind you that there is currently zero output.

All the control circuitry operates from an external 12V DC supply, which can be a 12V battery or plugpack. The maximum current drawn is about 360mA when all 16 relays are switched on (ie, when the output voltage is 10.000V). This drops to around 50mA when the relays are all switched off (output OFF).

The relays are operated directly from the incoming 12V via series diode D17, which is used for polarity protection. The rest of the circuit (IC1 and the LCD module) operates from a regulated +5V rail, derived from the 11.4V line via a 7805 3-terminal regulator (REG1).

The only other items to mention are the 4MHz crystal X1 (used for IC1's clock oscillator); trimpot VR1, which sets the contrast of the LCD module; and the 22Ω resistor connecting to pin 15 of the LCD module. The latter sets the current for the LCD module's LED backlighting.

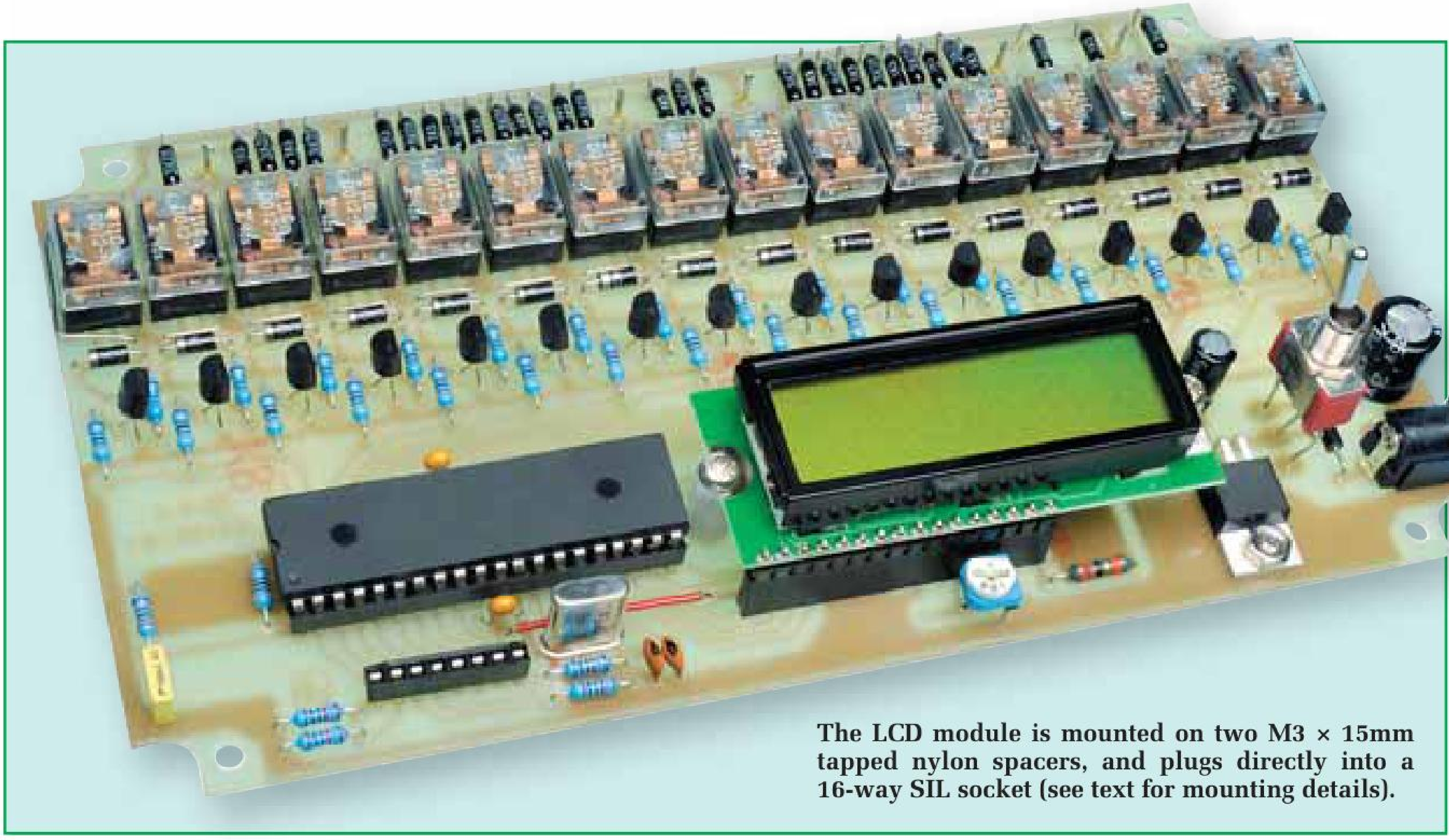
Construction

The *Digital Potentiometer* is fairly easy to build, with almost all components mounted directly on a single PC board, coded 856. Measuring 184mm × 99.5mm, this PC board is available from the *EPE PCB Service*. The board assembly fits snugly inside a standard UB2-size plastic box measuring 197mm × 113mm × 63mm. It mounts on the rear of the box lid on four M3 × 25mm tapped spacers.

The only parts not mounted directly on the PC board are power switch S1, the 4 × 4 keypad and the six binding posts. These all mount on the box lid, which forms the front panel.

Table 1: Resistor Colour Codes

	No.	Value	4-Band Code (1%)	5-Band Code (1%)
☐	4	10kΩ	brown black orange brown	brown black black red brown
☐	1	8.2kΩ	grey red red brown	grey red black brown brown
☐	16	4.7kΩ	yellow violet red brown	yellow violet black brown brown
☐	17	3.000kΩ	not applicable	not applicable
☐	1	2.2kΩ	red red red brown	red red black brown brown
☐	15	1.500kΩ	not applicable	not applicable
☐	16	47Ω	yellow violet black brown	yellow violet black gold brown
☐	1	22Ω	red red black brown	red red black gold brown



The LCD module is mounted on two M3 × 15mm tapped nylon spacers, and plugs directly into a 16-way SIL socket (see text for mounting details).

As you can see from the photos, the panel layout is a little unusual. The keypad, LCD readout and power switch are all in the lower part of the front panel, while the input and output terminals are along the top.

This has been done for two reasons, one being to make the completed unit easier to 'drive' when placed on a workbench or table. The other reason is that this PC board layout turned out to be the easiest and most logical. It allows the 16 mini relays and their drivers to fit in a row across the board between the ladder resistors at the top and the microcontroller circuit at the bottom. So while it may seem unusual, you'll find it's easy to build and quite intuitive to use.

Board assembly

The printed circuit board component layout is shown in Fig.5. Begin construction by fitting the 20 wire links, sixteen of which are arranged in a horizontal row just below the 16 relays. Note that the link under relay RLY16 at far left is 'U' shaped, as it must loop around the relay to complete the earth (0V) return line for the relay contacts.

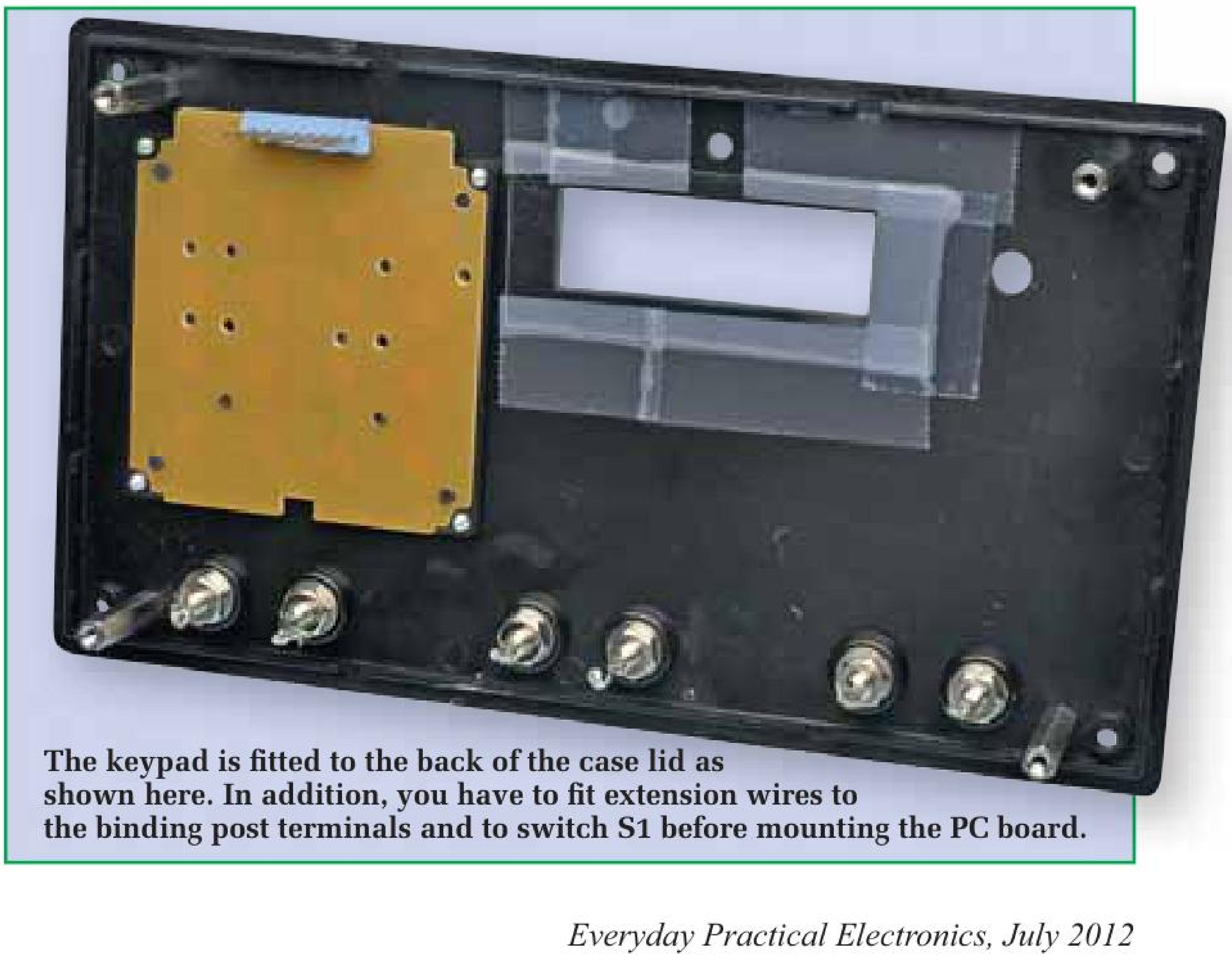
The remaining four links are in the lower half of the board, in the controller section. Two of these are under the LCD module, while a third horizontal link is located just below the microcontroller (IC1). The final link runs vertically at centre right, just above the 470μF electrolytic capacitor.

Once the links are in place, fit all the 'ordinary' (ie, 1%) resistors to the board. These include the 910kΩ resistors at the top (shown dashed) if you need them, plus all the resistors below the relays.

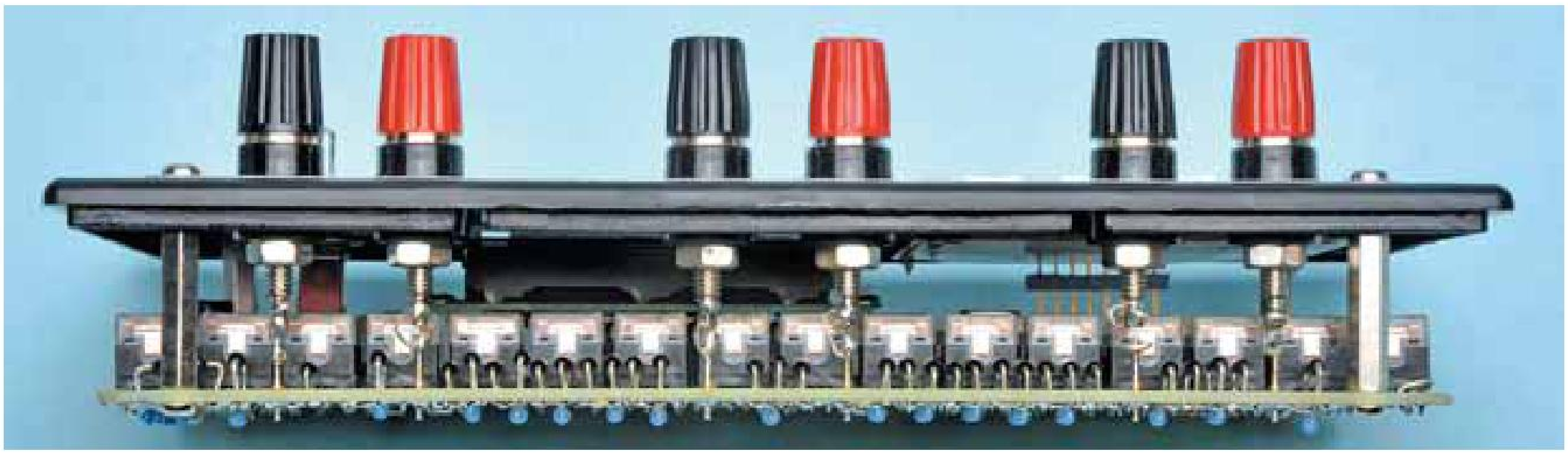
The 17 1N4004 diodes can now be installed, 16 of which run in a horizontal row just below the relays. These diodes all have their leads bent down quite close to their bodies, so take extra care when bending them. Take care also with their orientation – they go in with the cathode bands to the left.

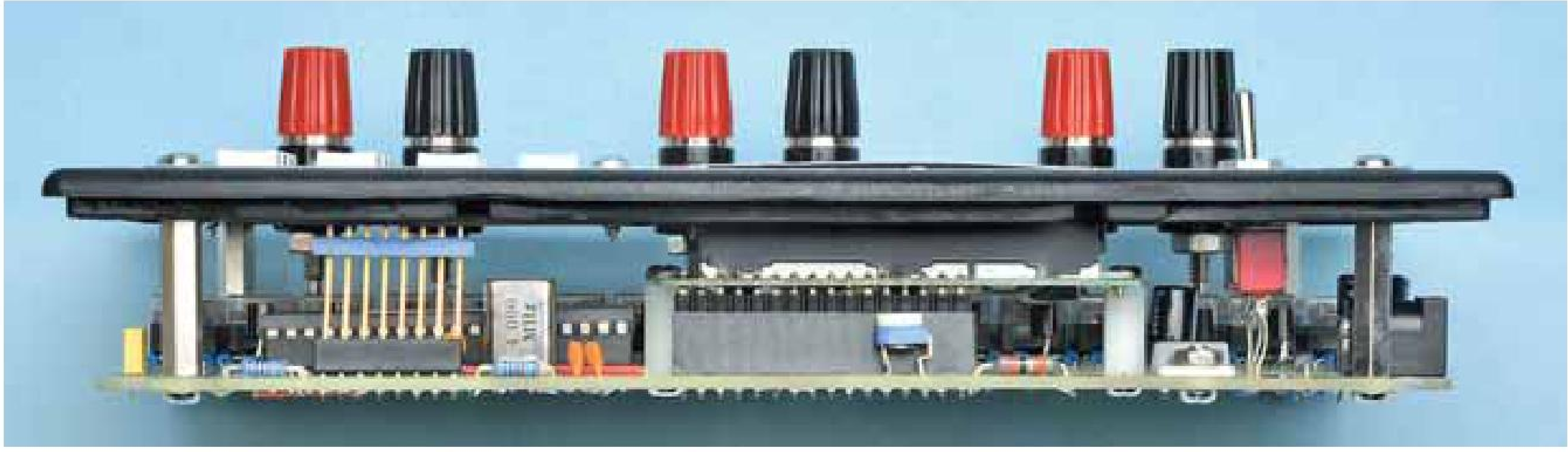
The last diode (D17) goes in just behind DC input socket CON1 at lower right. Note that its leads are bent down somewhat further away from the body and it's fitted with its cathode (K) towards the top of the board.

VR1 (the LCD contrast adjust trimpot) is next, followed by the



The keypad is fitted to the back of the case lid as shown here. In addition, you have to fit extension wires to the binding post terminals and to switch S1 before mounting the PC board.





The PC board is secured to the back of the lid on four M3 × 25mm tapped spacers, with the keypad's SIL pin header plugging into a matching socket. Ignore the resistors shown on the copper side of the PC board – this is a prototype and all resistors go on the top of the board in the final version.

capacitors. Most of the capacitors are relatively low-value unpolarised ceramic or metallised polyester types. The only two polarised capacitors are the 470μF and 220μF electrolytics, both of which go in at lower right. Make sure you fit these the correct way around.

Now you can fit DC input socket (CON1), the 40-pin socket for IC1 and the 16-way SIL socket for making the connections to the LCD module. Also fit an 8-way length of SIL socket strip for the keypad connections, at lower left on the board.

Driver transistors Q1 to Q16 are next. They must be orientated as shown in Fig.5, after which you can install crystal X1. Solder the crystal's leads quickly, so that it doesn't get too hot.

Regulator REG1 can now go in. It mounts flat on the board, with its leads bent down by 90° about 6mm from its body. Secure it to the PC board using an M3 × 6mm screw and nut *before* soldering its leads (warning: don't solder the leads first, otherwise you could crack the PC board tracks as the mounting screw is tightened down).

Once the regulator is in place, install the 16 mini relays (RLY1 to RLY16). These have a polarised pin layout, so they can only be fitted one way around.

Precision resistors

The 'precision' resistors in the ladder network all fit along the top edge of the board, above the relays. There are 32 of these in all, consisting of two different values: 3.000kΩ (0.1%) and 1.500kΩ (0.1%). Fit the 15 × 1.500kΩ resistors first, followed by the 17 × 3.000kΩ resistors.

It's a good idea to fit the 3.000kΩ and 1.500kΩ resistors with their bodies a couple of millimetres above the board. This will help ensure that the resistors are not overheated when their leads are being soldered to the copper pads underneath. You should also make the solder joints quickly, to minimise the risk of heat damage.

As mentioned previously, if you are unable to obtain 3.000kΩ 0.1% resistors, you can use 3.010kΩ 0.1% resistors instead. These must then each have a 910kΩ 1% resistor connected in parallel, to trim the values back to 3.000kΩ. Install these 910kΩ resistors only if necessary (they are shown dashed on Fig.5).

You can purchase 3.010kΩ resistors from either Farnell (Cat. 1083305, 9501886 or 1751494) or RS Components (Cat. 166-223).

LCD module

The only remaining component to install (apart from the PIC micro) is the LCD module. To do this, first attach two M3 × 15mm tapped nylon spacers to the main PC board at the indicated mounting positions. These spacers can be secured using M3 × 6mm machine screws, passing up from underneath.

Next, plug the long ends of a 16-way SIL pin header strip into the SIL socket just above trimpot VR1, pushing the pins in as far as they'll go. The LCD module is then be fitted in position, with the top ends of the SIL header pins passing through the holes in the lower edge of the module.

Push the LCD module all the way down so that it sits against the spacers, then secure it using another two M3 × 6mm machine screws. A fine-tipped soldering iron must be used to solder all 16 pins of the SIL header to the tiny copper pads along the top edge of the LCD module.

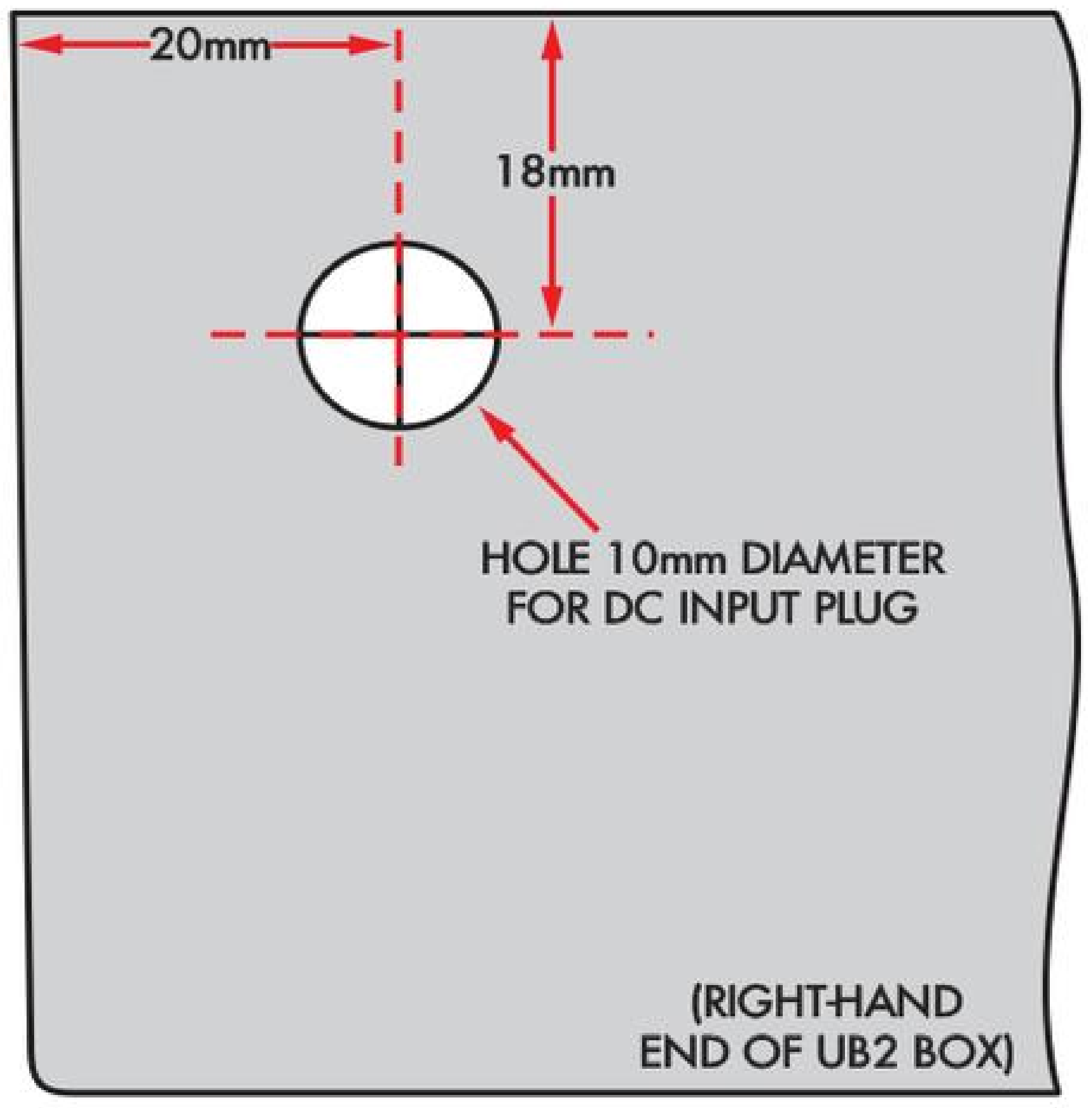

20mm
18mm
HOLE 10mm DIAMETER
FOR DC INPUT PLUG
(RIGHT-HAND
END OF UB2 BOX)

Fig.6: this is the drilling template for the DC power input socket access hole.

Having secured the LCD module, the next step is to carefully plug the PIC16F877A-I/P programmed microcontroller into its 40-pin socket. Be careful with its orientation – its notched end goes to the left.

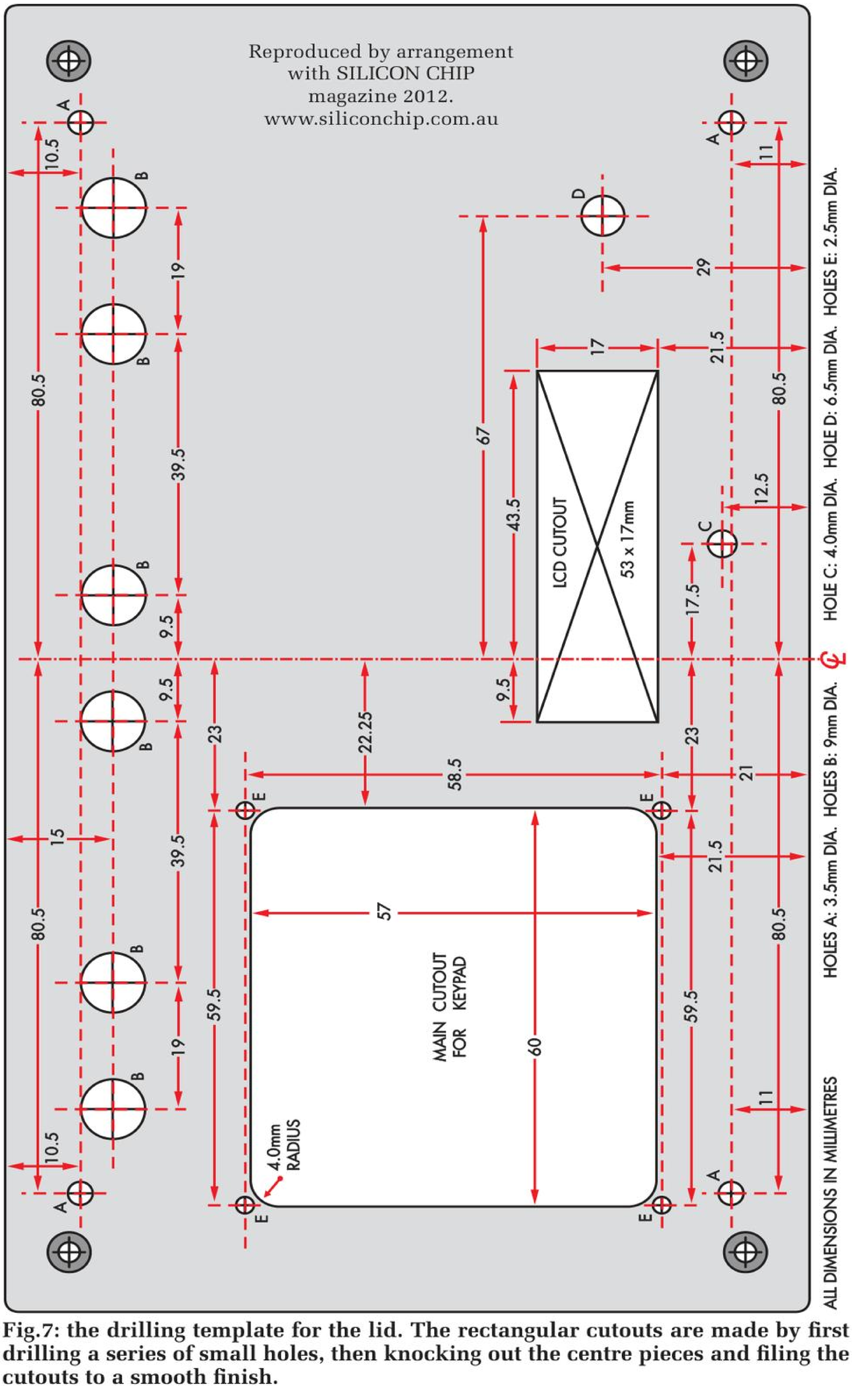
Preparing the case

At this stage, the PC board assembly is virtually complete. It can now be placed aside, while you prepare the front panel and case. Most of this preparation involves the lid – the case itself only needs to have a single hole drilled in the right-hand end to provide access to the 12V DC input socket (CON1). Fig.6 shows the drilling details.

The front panel (lid) drilling detail is shown in Fig.7. This diagram is actual size, so a photocopy of it can be used as a template. Note that the 6.5mm and 9mm holes are best made by first drilling small pilot holes and then carefully enlarging them to size using a tapered reamer. That way, you can position them more accurately.

The two large rectangular cutouts are for the the LCD viewing window and the keypad. These are made by drilling a series of small holes around the inside perimeter of the marked area, then knocking out the centre piece and filing the job to a clean finish.

You are now ready to fit the front panel. Fig.8 shows the full-size front-panel artwork. This can be photocopied, laminated and attached to the lid using double-sided adhesive tape. The various mounting holes cut out using a sharp hobby knife.


Reproduced by arrangement with SILICON CHIP magazine 2012. www.siliconchip.com.au

A
B
C
D
E
10.5
80.5
19
39.5
9.5
23
22.25
67
43.5
17
29
11
21.5
12.5
17.5
21
58.5
15
59.5
57
60
LCD CUTOUT
53 x 17mm
MAIN CUTOUT FOR KEYPAD
4.0mm RADIUS
HOLES A: 3.5mm DIA. HOLES B: 9mm DIA. HOLE C: 4.0mm DIA. HOLE D: 6.5mm DIA. HOLES E: 2.5mm DIA.
ALL DIMENSIONS IN MILLIMETRES

Fig.7: the drilling template for the lid. The rectangular cutouts are made by first drilling a series of small holes, then knocking out the centre pieces and filing the cutouts to a smooth finish.

Front panel assembly

The 4 × 4 matrix keypad mounts on the front panel in the larger cutout. However, before mounting it, you need to fit an 8-way length of 'long-pin' SIL strip to the pads on the lower edge of the keypad board (to mate with the 8-way SIL socket on the main board). This is done by pushing the pin strip pins up through the holes near the lower edge of the keypad board so that they protrude by about 1mm – just enough to allow you to solder each pin to its mating copper pad.

Once the pin strip is fitted, the keypad can be passed up through the front-panel cutout and secured using

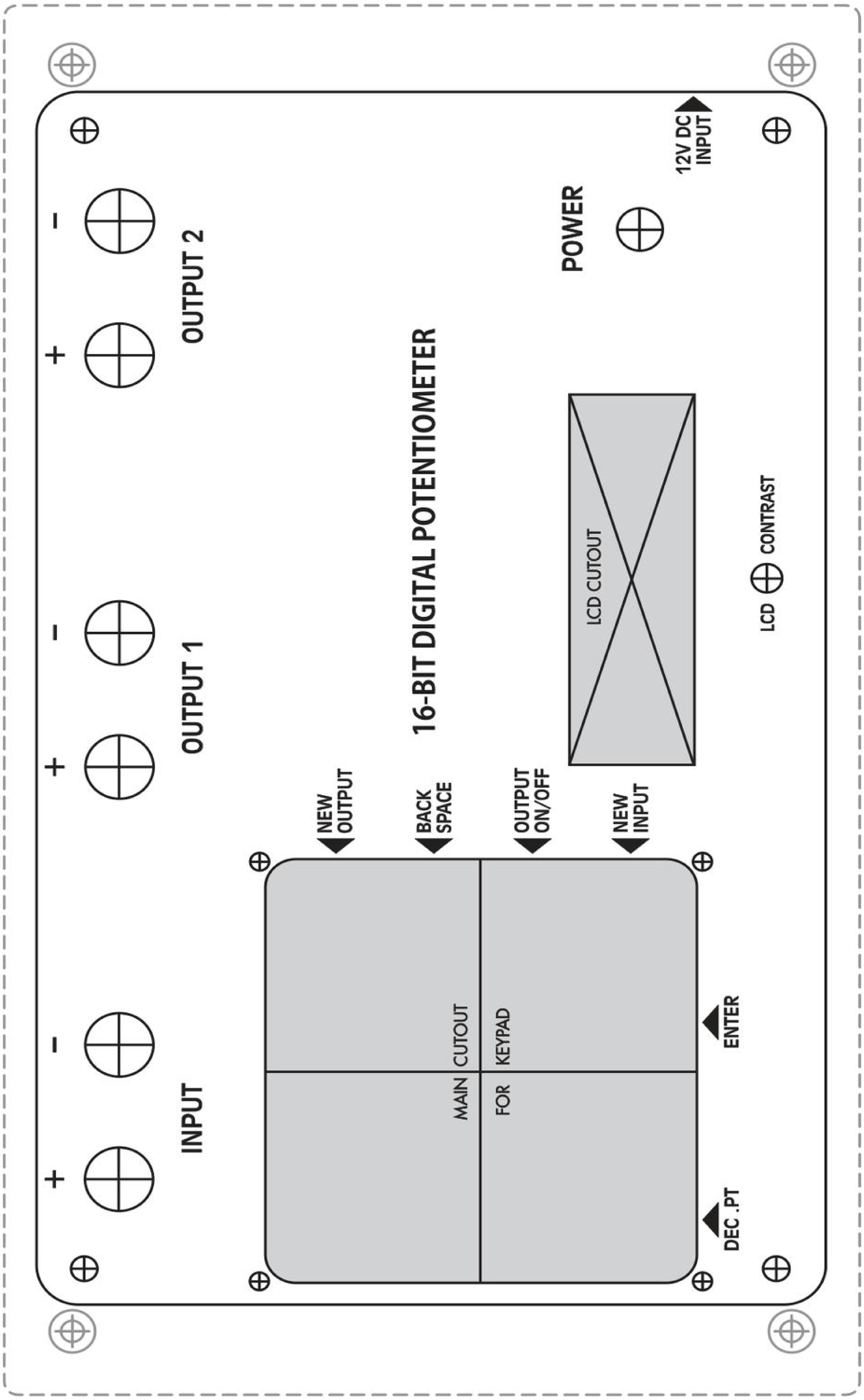


Fig.8: this full-size front panel artwork can be copied, laminated and attached to the case lid using double-sided adhesive tape.

four No.5 self-tapping screws. You can then fit the mini toggle switch (S1) at lower right and the six binding post terminals along the top edge.

Extension wires

That done, solder 25mm-lengths of 0.7mm tinned copper wire to the three connection lugs at the rear of S1 and to the rear spigots of the six binding posts. These 'extension wires' are to make it easier to complete the connections between these parts and the main PC board when the board is subsequently mounted behind the panel.

Next, attach a 65mm × 25mm rectangle of thin, clear plastic (1mm perspex or similar) behind the cutout for the LCD panel (ie, to the rear of the front panel). This can be secured using either a few spots of contact cement or strips of adhesive tape around the edges.

Once it's in place, attach the four M3 × 25mm spacers to the rear of the lid using M3 × 6mm machine screws. Don't tighten these screws completely just yet though, because the spacers may need to be moved slightly when mounting the PC board assembly.

This next step is slightly tricky. That's because you need to make sure that the 'extension wires' attached to switch S1 and the six binding posts pass through their matching holes in the board. At the same time, the pins of the 8-way SIL strip attached to the keypad must go into the matching header socket. This isn't all that difficult to do, but you do need to be both careful and patient to get it right.

Push the board down until it rests on the spacers, then secure it using four more M3 × 6mm machine screws. The screws attaching the spacers to the front panel can then be tightened, after which the complete assembly can be upended and the various extension wires soldered to their pads on the board.

Your new *16-Bit Digital Potentiometer* is now complete.

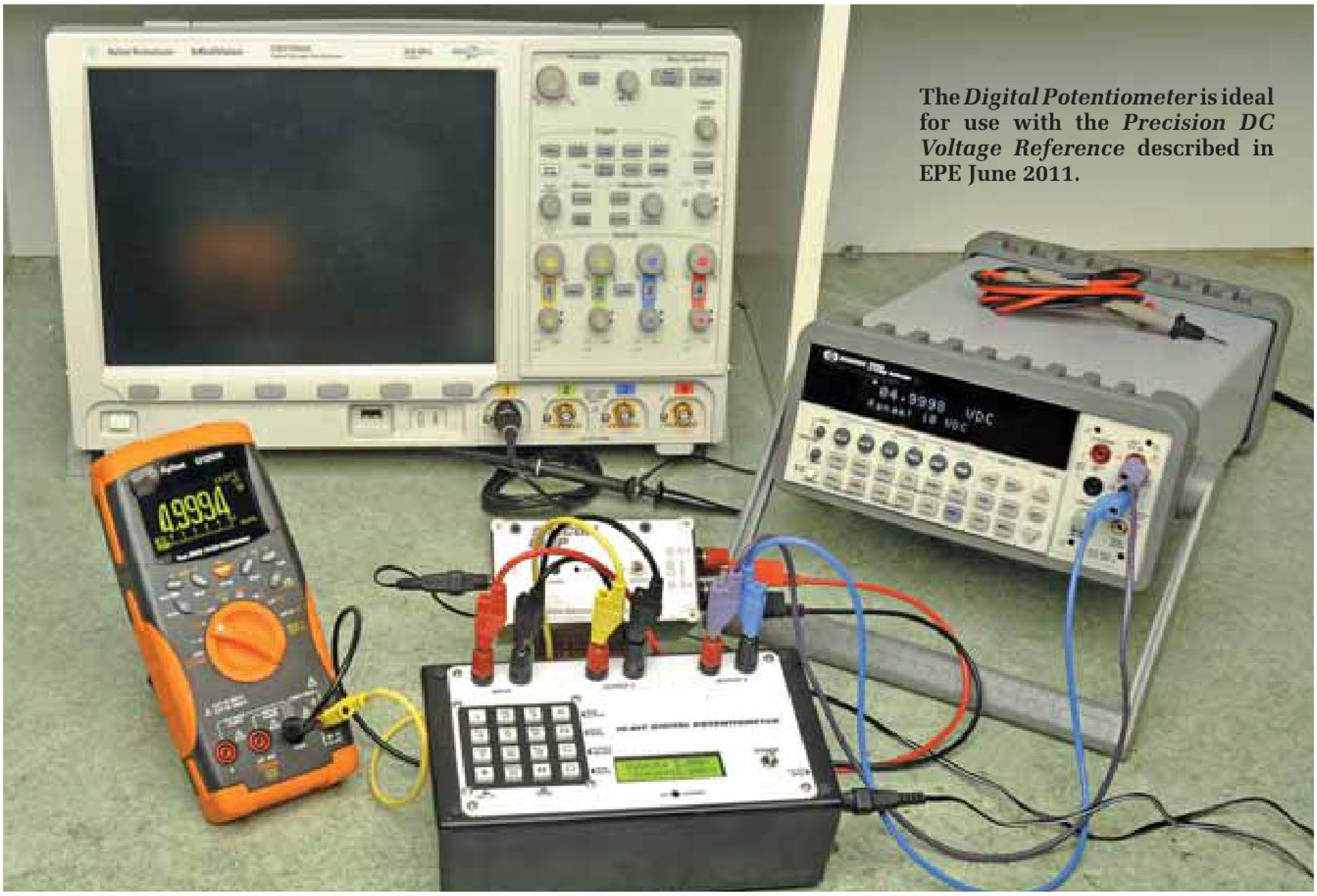
Checkout time

All you need for the initial checkout is a source of 12V DC capable of supplying 400mA or more. This can be either a 12V battery or a suitable mains plugpack. Fit a 2.5mm (ID) concentric plug to its output lead (positive to the centre pin) and plug it into CON1.

When you switch the power on via S1, you should be greeted by a warm yellow-green glow from the LCD module's backlighting. You should also see the initial greeting message, ie, '16-Bit Digital Potentiometer'. If this isn't displayed clearly, adjust trimpot VR1 with a small screwdriver to set the LCD module for optimum contrast.

By the time you do this, you should find that the message displayed has changed to 'Output = OFF' on the top line and '(Input = 10.000V)' on the bottom line. This shows the default start-up settings, ie, with the divider relays all turned off, so there is zero output and the firmware set for an assumed divider input voltage of 10.000V.

If everything checks out so far, try pressing the keypad's 'C' (output toggle) key for about 300ms. This should



The *Digital Potentiometer* is ideal for use with the *Precision DC Voltage Reference* described in EPE June 2011.

result in the top line of the LCD display changing to 'Output = 5.000V'. At the same time, you should hear a faint 'click' as some of the relays are energised to set the divider to the appropriate division ratio.

Assuming everything has happened as described, the unit has passed its initial checkout and can be fitted into its box to complete the assembly.

Using it

Using the *Digital Potentiometer* is very straightforward.

The first step is to connect its input terminals to the output of your voltage reference (eg, the 10.000V *Precision Voltage Reference* described in *EPE*, June 2011). It's best to use external sensing and a four-lead connection. That way, the voltage reference will maintain an accurate output voltage right at the *Digital Potentiometer's* input terminals.

One pair of the *Digital Potentiometer's* output terminals is then connected to the DMM (or to any other instrument you want to check). The other output terminal pair can be connected to another DMM (eg, if you want to use this as a reference).

It's now just a matter of applying power and using the keypad to enter the desired output voltage. This is done by first pressing the 'A' key, and then keying the voltage in as a five or six-digit number, including the decimal point (which is keyed in using the '*' key). If you make any errors, they can be corrected using the 'B' key, which acts as a destructive backspace. The LCD readout shows the keypad entries.

If you are keying in a voltage of 9.999V or less, you only need to key in the significant digits, including the decimal point. You then press the '#' key, which is used here as an Enter key. The micro will then automatically fill in the remaining digit positions with zeros.

For example, if you key in '2.3#', this will give an output voltage of 2.300V.

The only variation from this sequence is if you key in an output voltage like 10.000V, which does require you to key in the full six values (including the decimal point). In that case, there's no need to press the '#' (Enter) key at the end in order to get the micro to accept this voltage setting. It will do so automatically after the sixth digit is keyed in.

If you need to disable the *Digital Potentiometer's* output voltage at any time, this is done by pressing the 'C' key. The output can then be re-enabled by pressing the 'C' key again (ie, 'C' toggles the output on and off).

All of the above assumes that you are using the *Digital Potentiometer* with our June 2011 *Voltage Reference*, with its output of 10.000V DC. However, as mentioned earlier, the *Digital Potentiometer* is also suitable for use with other references, including those with output voltages such as 8.192V or 5.000V.

All that is necessary to use it with other reference voltages is to key in the new input voltage. This is done in a very similar way to keying in a new output voltage. The only difference is that before keying in a new input voltage you press the 'D' key instead of the 'A' key.

That's it – we hope you find the *16-bit Digital Potentiometer* a useful addition to your workbench. ***EPE***

Take Time and Cost out of Embedded Design

With Microchip Development Tools

MPLAB ICD 3
MICROCHIP
MPLAB X
Integrated Development Environment
MPLAB REAL ICE
PICkit 3
Cross-Platform • Universal • Open-Source

With over 1.15 million development systems already shipped, Microchip Technology has a reputation for providing a comprehensive range of world-class, low-cost, easy-to-use application development tools. Combining Microchip's powerful free MPLAB® IDE with application- and product-specific starter kits cuts the cost and complexity of your embedded designs.

MPLAB X IDE is the new single, universal graphical user interface for Microchip and third party software and hardware development tools. It is the industry's only IDE to support an entire portfolio of 800+ 8-bit, 16-bit and 32-bit PIC® MCUs, dsPIC® DSCs and memory devices. It includes a feature-rich editor, source-level debugger, project manager, software simulator, and supports Microchip's popular hardware tools, such as the MPLAB ICD 3 in-circuit debugger, PICkit™ 3 starter kit, and MPLAB REAL ICE™ in-circuit emulator.

Based on the open-source NetBeans platform, MPLAB X runs on Windows® OS, MAC® OS and Linux, supports many third-party tools, and is compatible with many NetBeans plug-ins.

Add starter kits, reference designs and webinars for specific PIC MCU and dsPIC DSC families and you have all the tools you need to fast-track your embedded design. The low-cost starter kits help you to use application-optimised PIC MCU and dsPIC DSC families in wireless and wired networks, security, motor control, automotive and low-power designs, as well as in graphics and general-purpose applications.

Start now! Download the MPLAB IDE Quick Start manual at:
www.microchip.com/tools

THE MPLAB® IDE TOOLKIT FOR FAST AND EFFECTIVE EMBEDDED DESIGN:

MPLAB® ICD 3 - DV164035

MPLAB® REAL ICE™ - DV244005

PICkit™ 3 Debug Express
- DV164131

MICROCHIP

Microcontrollers • Digital Signal Controllers • Analog • Memory • Wireless

The Microchip name and logo, the Microchip logo, dsPIC, MPLAB and PIC are registered trademarks of Microchip Technology Incorporated in the U.S.A. and other countries. PICkit, PICDEM and REAL ICE are trademarks of Microchip Technology Incorporated in the U.S.A. and other countries. All other trademarks mentioned herein are property of their respective companies. © 2012, Microchip Technology Incorporated. All Rights Reserved. ME1015AEng/04.12

TechnoTalk

How do they do it?

Mark Nelson

You have probably seen those giant electronic billboards in city centres, but did you ever wonder how the advertisements are posted and changed? Mark reveals all.

WATCHING a traditional billposter at work is to see an art installation under construction. Perched high atop a ladder, he (this seems to be an exclusively male occupation) tacks one small corner of the sheet on to wet paste and then unfolds and fixes a huge paper advertisement with remarkable deftness and speed. Sorry if I seem to be waxing lyrical but it's true, isn't it?

Sheets to the wind

The large billboards that you see at major road junctions can run to 96 sheets, although the 32-sheet ones (approximately 12ft high by 24ft wide) are more common. Setting aside for a moment the skill required to post these monster messages, the underlying technology is agreeably low-tech and simple to comprehend.

Simplicity has its downside, though. Substituting a different message for a single day or weekend is no trivial matter; it's technically feasible, but desperately expensive. No wonder then, that electronic billboards are gaining popularity among advertisers, not just for their near-instantaneous updateability, but also for their greater interactivity.

They're everywhere now. You can find ever-changing digital billboards at bus stops, and show screens and advertisements to guide shoppers in retail malls. While on the London Underground there are both giant flat (well, curved) screens at platform level and long arrays of smaller screens running up and down the escalators.

Perhaps the most impressive, however, are the vast 48 and 96-sheet billboards in city centres and airport approaches. These are backlit devices using similar display technology to high-definition TV.

Highly interactive

What particularly excites advertisers is the ability to interact with the public. Digital billboards that display several different advertisements are nothing special nowadays, nor even those that alter their messages according to the time of day.

At bus shelters in Canada, these techniques enticed people to interact with digital billboards equipped with pressure sensors. On one electronic poster was a patient whose heart had stopped, with a hand print on the chest marked 'Push Here'. Anyone who pushed them saw the electrocardiogram monitor starting to bleep again, as if the patient's heart had just come back to life, followed by the message 'Choose a Career in Public Health'.

In the US, last September, CBS demonstrated an even more imaginative demonstration of interactive billboards that had the appearance of mirrors. When passers-by stop to look, sensors zeroed in on their faces and displayed the message 'Person of Interest Identified', followed by 'Taking Photo'.

Their photo was then taken and then incorporated into the display, accompanied by a phone number and identification number to send a text-message. If people then did this, they received a link to their 'classified file' and could post the photo on Facebook or Twitter.

Do these applications sound trivial? Probably, but do not underestimate the technology. The time will inevitably come when the act of pausing to read an advertisement will activate Bluetooth or some other wirefree technology to send a text to your mobile device directing you to the nearest sales outlet and offering you an 'exclusive' personal discount, if you purchase within the next hour.

Clever connectivity

So far, so good. Digital billboards are clearly a growing force in advertising, but how do you alter these giant screens with up-to-date video, data, graphics and animation in just a matter of seconds? By using the Internet, obviously. And your line of thought probably leads to wired broadband. But not every location has a convenient connection to hand, and in any case, wireline connections are inherently vulnerable to vandals and other ne'er-do-wells who might have designs on these billboards (see next section).

A far superior solution, according to Glasgow-based Stream Communications, is mobile wireless technology. Stream claims to be Europe's leading provider of enhanced GSM, GPRS and 3G mobile network services for the machine-to-machine (M2M) sector, providing its own bespoke SIM cards and platform for the specialised M2M connectivity on which digital billboards rely.

The company's own mobile virtual network is claimed to make digital billboards a simpler and more cost-effective proposition than other solutions, especially as you could install and assign at one location for a particular event, and then move it to another location. In this scenario, providing a wireline broadband connection for a short period would be very expensive. The cost of changing messages is minimal, so an advertisement that for some reason fails to motivate people to, say, visit a website could be changed very rapidly.

Hacker alert

Any device that's updated by wireless could be hacked by miscreants, at least potentially. And that's precisely what happened as far back as 2008, when a notorious 18 year-old graffiti artist by the name of 'Skullphone' extended his repertoire of vandalism to include ten digital billboards around Los Angeles. Onlookers were treated to Skullphone's calling card running in-between the normal advertisements above city streets. However, all was not what it seemed, since the apparent hack attack was an unorthodox art installation and entirely legitimate.

The respite did not last long, however, and in January 2010, a man in Russia brought Moscow traffic to a standstill after he hacked into the server of an advertising agency and used its electronic billboard to show porn to motorists. Igor Blinnikov, a shipyard fitter aged 41, chose a 20ft × 30ft billboard next to the Interior Ministry building on the Garden Ring for an exploit that he thought would be fun. The authorities thought otherwise and sent him down for six years.

You'll have to imagine Blinnikov's exploit, but you can see an amusing short video on YouTube (**http://tinyurl.com/6ywfhbq**) which shows a guy in Times Square, New York purporting to use a low-power video transmitter in March 2011 to transfer images from his iPhone to a number of electronic billboards. It's clear that he is using 'brute force' technology here, swamping the displays only when his micro-transmitter is within literally inches of the billboard.

Before this, a spirited young lady set out the theoretical possibilities of a kind of hacking that was clearly still in its infancy. Go to **http://tottenkoph.com/presentations/** and scroll down to Hacking the outdoor digital billboard network for an 18-minute video presentation and other resources.

An Intelligent 12V

Does your computer make more noise than it should? It's probably mostly fan noise! Slowing the fans down will reduce the noise, but if you go too far you could end up with fricassee of CPU!

IN A TYPICAL personal computer, most of the noise – and it can be significant – comes from the cooling fans. That's because they run at full tilt all the time, regardless of the temperature, inside the case or out.

You *may* need to run the fans at full speed when you are encoding home movies on a 30°C day, but most of the time they just blow air around, creating a lot of noise.

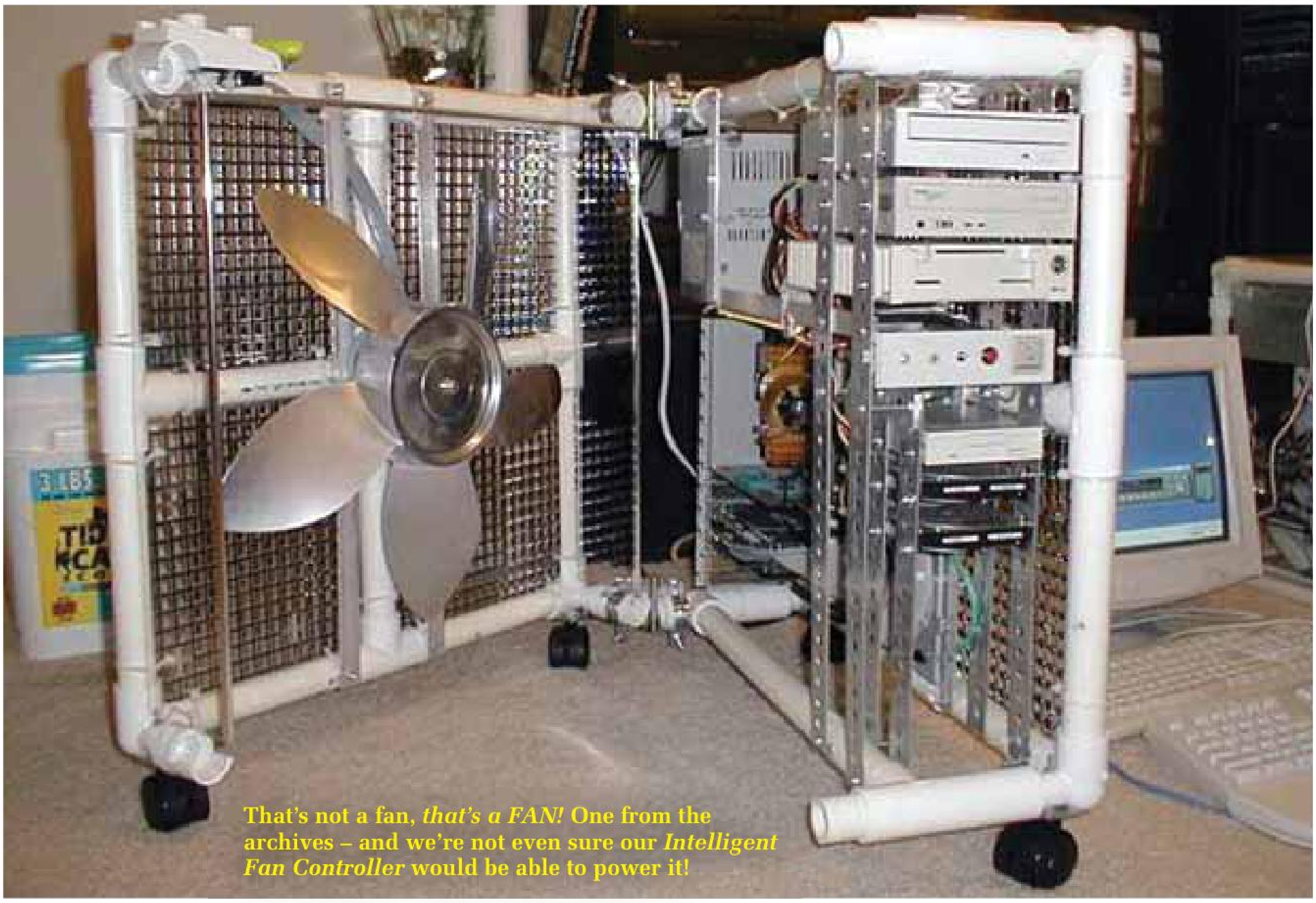
This can be especially bad if you have a Media Centre PC in an otherwise quiet lounge or home theatre. If you would like to hear the 'sounds of silence' then this project could be just what you need.

Using just two ICs and a handful of components, this intelligent fan controller will regulate the speed of up to eight 12V fans. It will measure up to four temperature points and use this data to smoothly control the speed of the fans, from completely off to fully on.

There are other ways to control the speed of fans, but they tend to be rather crude. That is why we called this project an *Intelligent 12V Fan Controller*.

One of the crude methods, unfortunately far too common, is to simply wire the fans to 5V rather than 12V. They will then run much quieter but more importantly, they will not be able to do their job on a hot day – and you risk incurring the damage that the fans were installed to avoid.

Another simple method of control is to wire a variable resistor (potentiometer) in series with the fans. You can buy some fancy looking controls that will mount on your computer's front panel; some even include a temperature display.



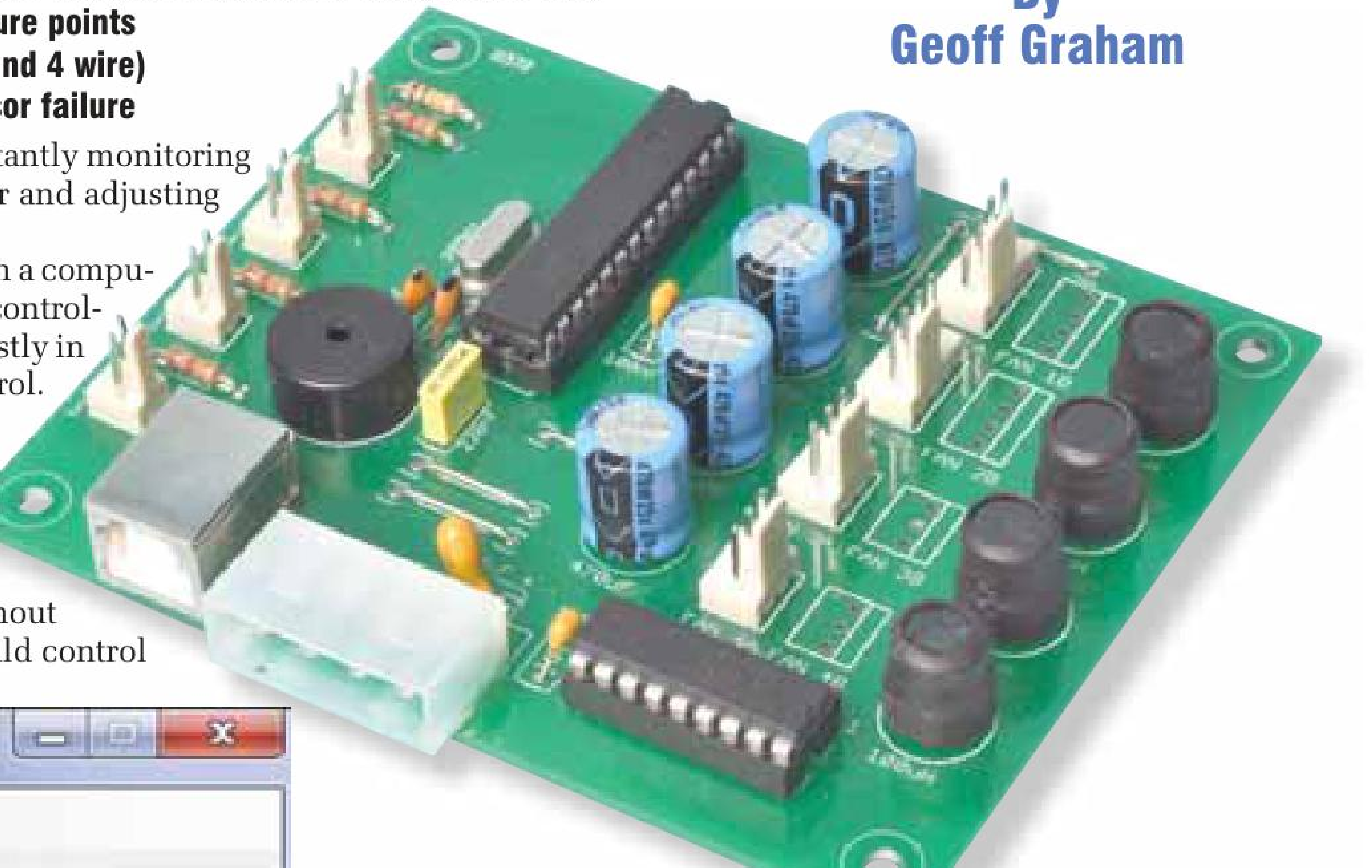
That's not a fan, *that's a FAN!* One from the archives – and we're not even sure our *Intelligent Fan Controller* would be able to power it!

2V Fan Controller

High Points

- **Control up to eight computer fans based on the measured temperature**
- **Windows software for configuration and display of temperatures and fan speeds**
- **Stand alone (does not need the Windows software or computer to run)**
- **Monitor up to four temperature points**
- **Works with most fans (2, 3 and 4 wire)**
- **Audible alarm on fan or sensor failure**

By
Geoff Graham



However, that requires you to be constantly monitoring the temperature inside your computer and adjusting the 'resistor' accordingly.

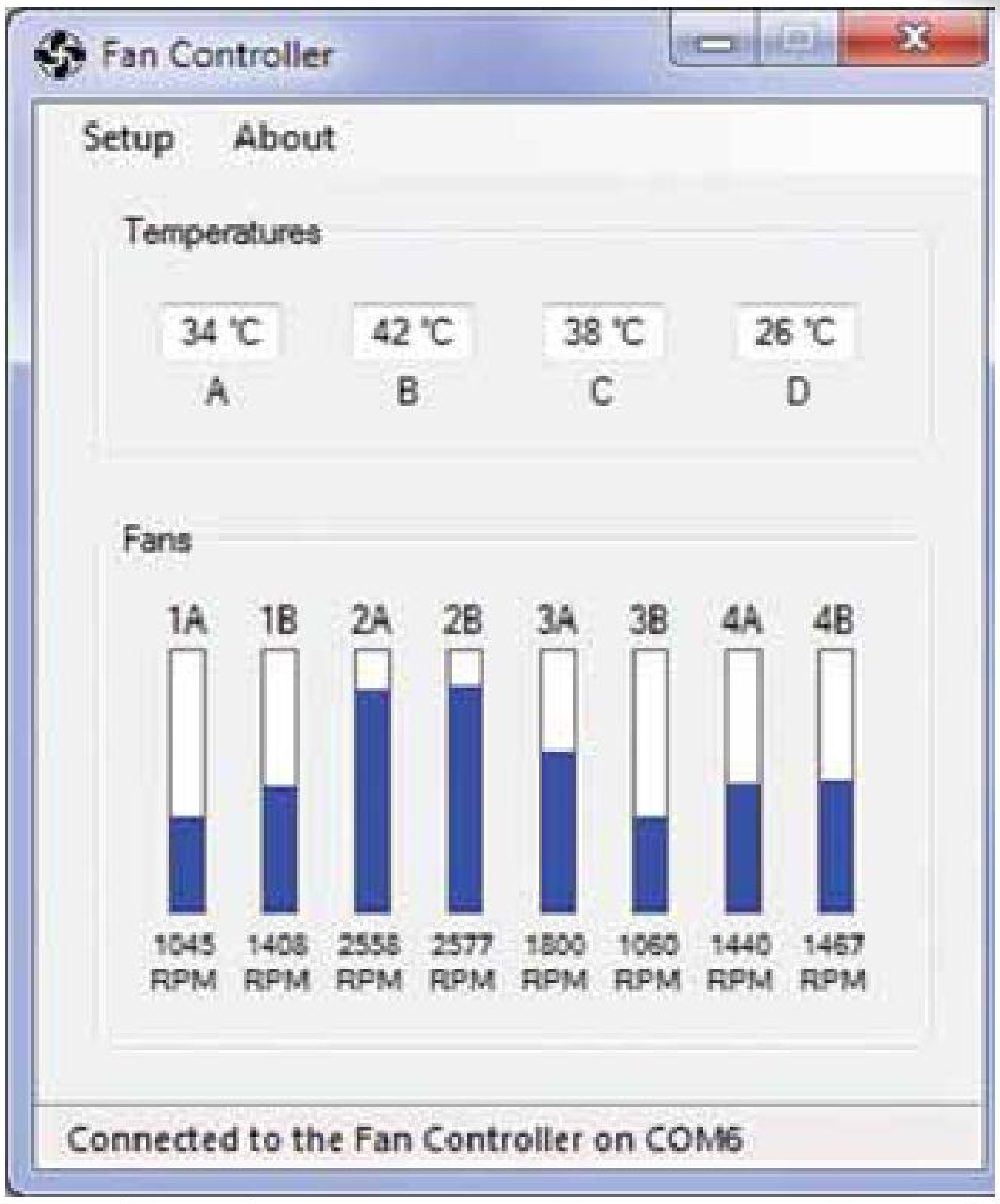
You may be fortunate enough to own a computer with a motherboard that has a fan controller, but even they have limitations, mostly in the number of fans that they can control.

Not just computer fans

While computer fans are the obvious target, this *Fan Controller* is certainly not limited to computers. Because it can run independently (without being connected to a computer) it could control the fans in a greenhouse, home brewery or just about anything else that uses small (12V) fans. Just bear in mind the current limitations mentioned later in this article.

Controller details

The *Intelligent 12V Fan Controller* is built on an 100mm × 80mm PC board, designed to fit in a spare 3½ or 5¼-inch drive bay, or any other handy spot inside your computer's case.



Temperatures

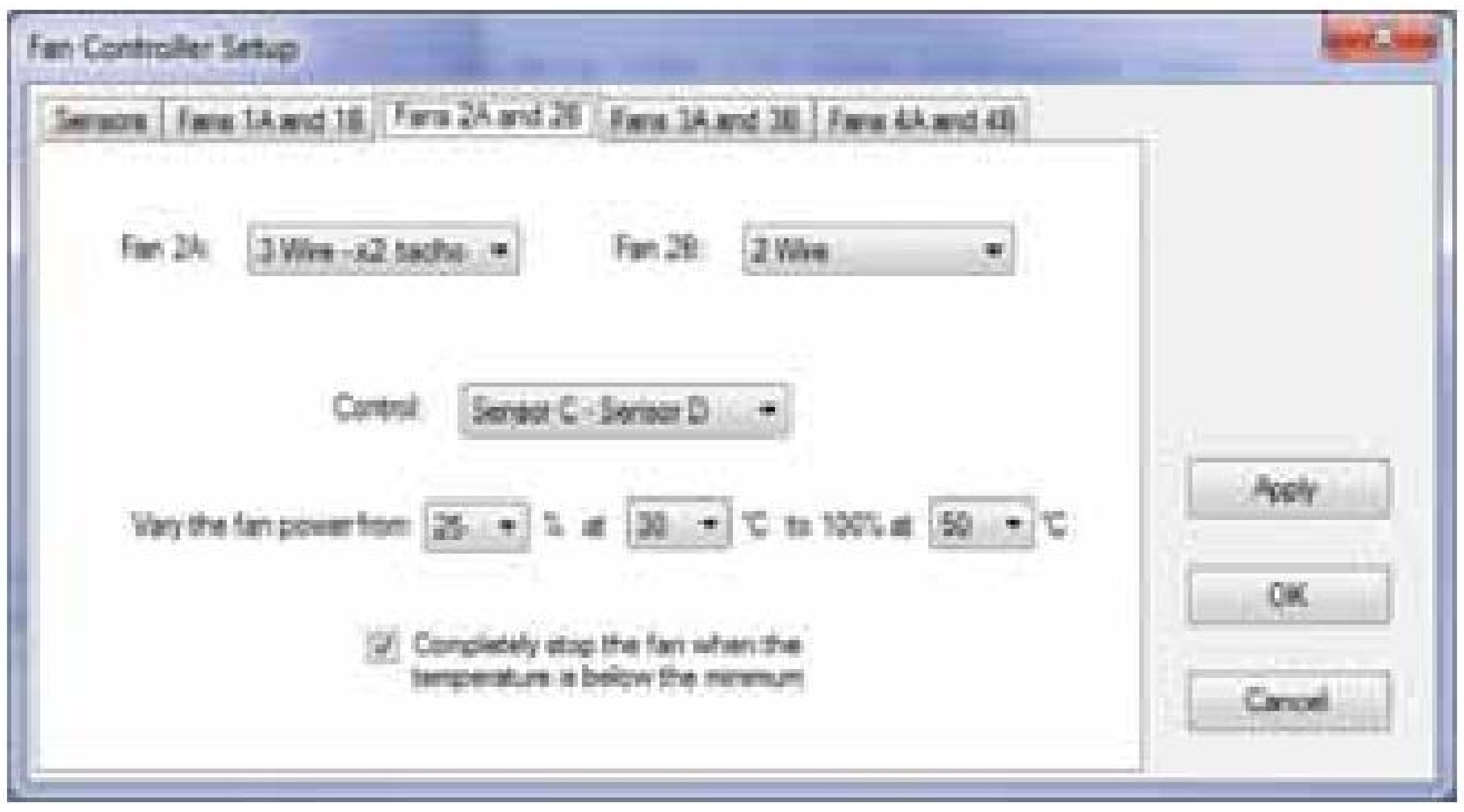
A	B	C	D
34 °C	42 °C	38 °C	26 °C

Fans

1A	1B	2A	2B	3A	3B	4A	4B
1045 RPM	1408 RPM	2558 RPM	2577 RPM	1800 RPM	1060 RPM	1440 RPM	1467 RPM

Connected to the Fan Controller on COM6

Fig.1: the Windows program running on your computer. This is optional, but it will show you the measured temperatures (in °C or °F) and the speed of the fans in RPM. If a sensor or fan fails, the entry will be coloured red and an audible alarm sounds.



Fan 2A: 3 Wire - x2 tacho

Fan 2B: 2 Wire

Control: Sensor C - Sensor D

Vary the fan power from 25 % at 30 °C to 100% at 50 °C

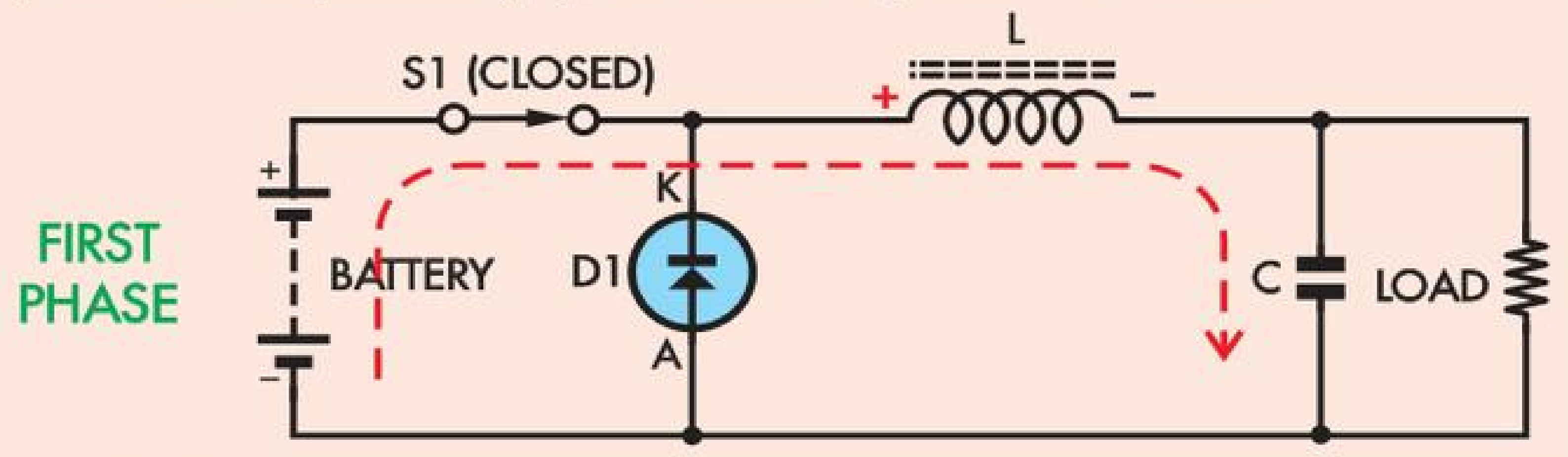
☑ Completely stop the fan when the temperature is below the minimum

Fig.2: an example of the setup screen for a pair of fans. You can select the type of fan, what sensors are used to control the speed, and the characteristics of that control. In this case, the fan is controlled by the difference in two temperatures, which would be the inlet and exhaust air temperatures.

Buck converters explained

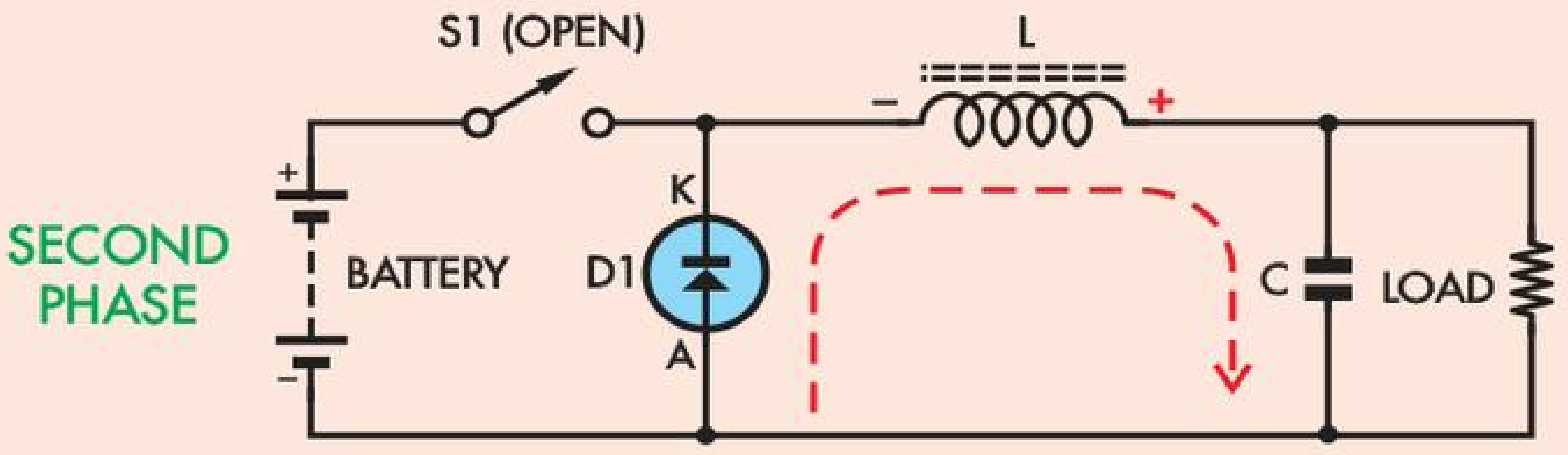
A buck converter is an efficient way of converting a higher voltage to a lower voltage, without throwing away the excess energy as heat. Most battery-operated gadgets (eg, mobile phones, iPods) will use one or more buck converters in an effort to get the best use of the energy in the battery while supplying the various voltages required in the device.

A buck converter consists of a switch (always a semiconductor switch), a diode, inductor and capacitor, as shown below. The load is represented by the resistor. At the start of a cycle (first phase) the switch (S1) is closed and current will flow through the inductor (L) into the capacitor (C), as shown by the red arrow.



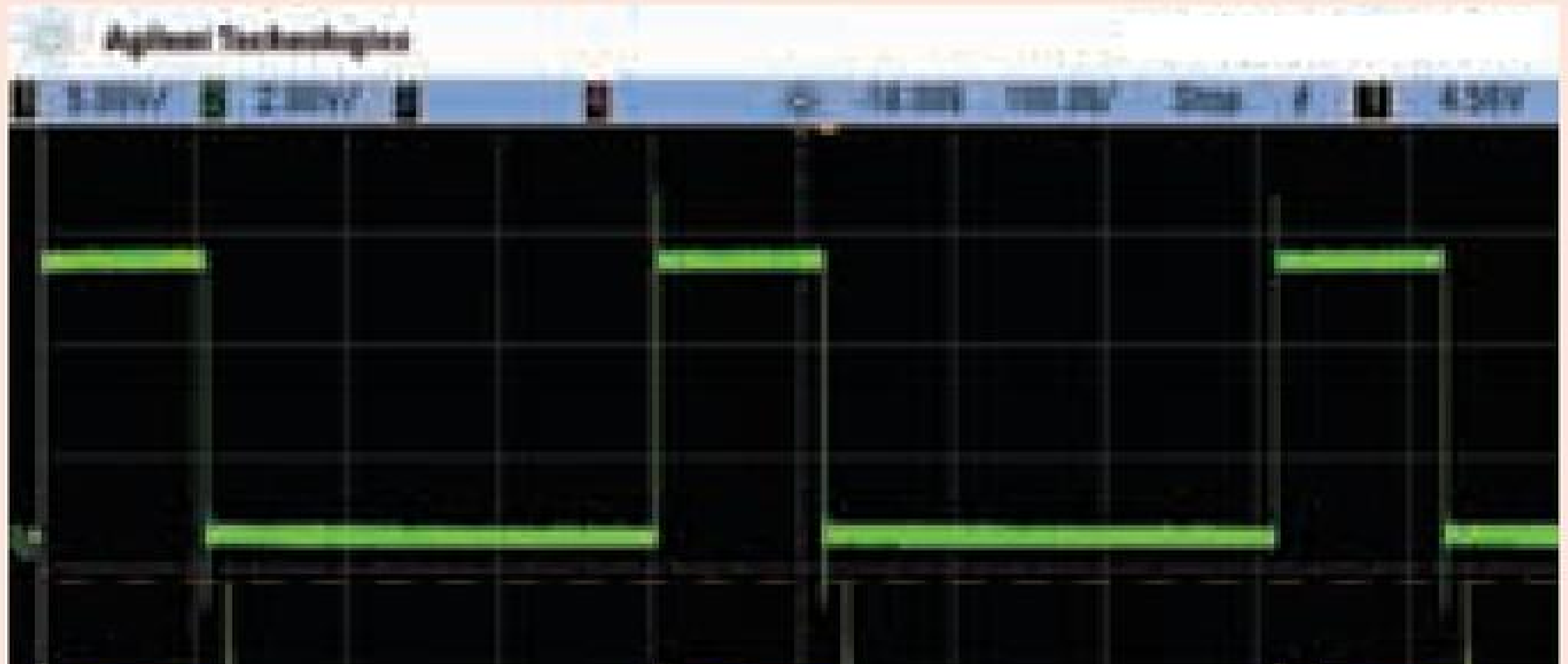
This current will be limited by the inductance of the inductor and the longer the switch is closed the higher the resultant energy stored in the capacitor. In the *Intelligent Fan Controller* we hold the semiconductor switch closed for up to 170μs.

When the switch is opened (second phase, as shown below), the magnetic field in the inductor will collapse, causing a spike of current which is conducted by the diode to further add to the charge in the capacitor. In the *Intelligent Fan Controller* this phase lasts for up to 230μs.



Finally, there is an idle period before the cycle restarts. The overall effect is that the capacitor is topped up with 'blips' of current, while the load continuously draws current from it.

If you open and close the switch rapidly (eg, >300kHz) you can get efficiencies up to 95% and a smooth output voltage. In the *Intelligent Fan Controller* we switch at 2.5kHz, which is easier to implement but results in a lot of ripple on the output. This does not matter as a fan will happily ignore quite high levels of ripple.



This 'scope grab shows the switch control voltage at the top and the switch voltage (at D1's cathode) at the bottom.

It has a USB 2.0 interface, which works with software running on a Windows-based computer. Using this software you can monitor the various temperatures and the speed of the fans under control. It also provides an interface for configuring the controller for different types of fans.

Fig.1 shows the software in its monitoring mode, with the various measured temperatures (in °C or °F) and the speed of the fans in RPM (if they are fitted with a tachometer output). If a fan or a temperature sensor fails, its entry will be highlighted in red and an alarm on the *Intelligent 12V Fan Controller* PC board will sound.

Fig.2 shows the software in its setup mode. As you can see, you can select the type of each fan, the temperature sensor used, the fan's minimum speed and the range of temperatures that will control the speed of the fan.

As well as selecting any one of the temperature sensors (named A to D), you can also select the difference between one of the first three sensors (A, B or C) and the last sensor (D). This allows you to control the fan speed based on the difference between the ambient (or incoming air) temperature and the exhaust temperature.

In most cases the *Fan Controller* will only need to monitor one or two temperatures. The provision for four inputs is intended for those with very complicated requirements. Similarly, most people will have far less than eight fans in their computer (although we've seen some with many more!).

The controller will accommodate most types of the fans found in computers these days. These include the standard 2 and 3-wire fans and the latest 4-wire fans that are controlled by a pulse width modulated (PWM) signal. The 'Know your fans' panel describes all these fans in detail.

The design can independently control four pairs of fans or a total of eight fans. Each pair is independent and can be separately configured for different control characteristics.

Buck converter

The speed of 2 and 3-wire fans is controlled by varying their supply voltage using a circuit called a 'buck converter'. To understand how this is done, refer to the full circuit diagram for the *Intelligent 12V Fan Controller*, shown in Fig.3.

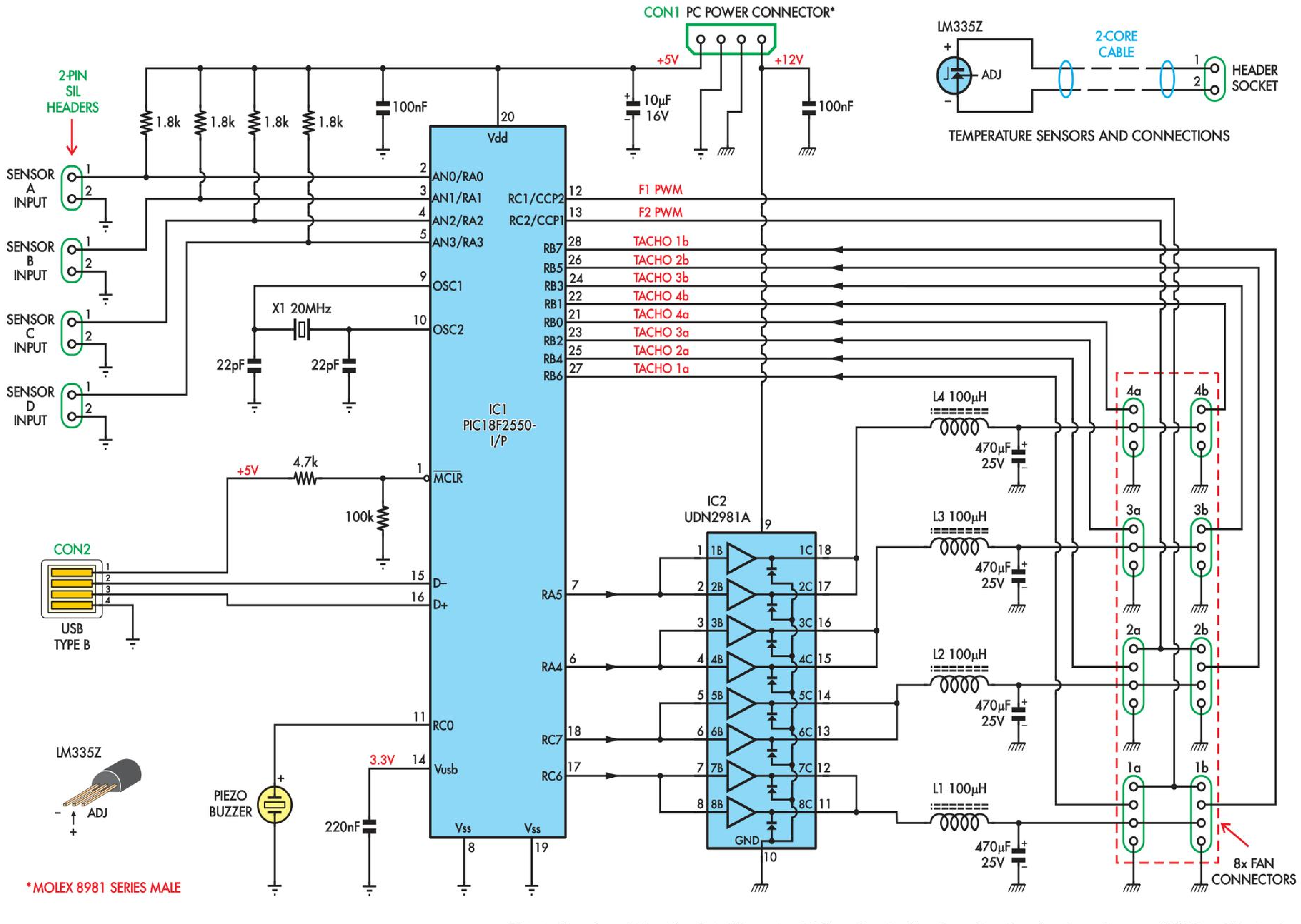
Taking the components associated with fans 4A and 4B as an example, the microcontroller generates a continuous string of pulses on its pin 7 (RA5) output. The frequency of the pulses is 2.5kHz, and the microcontroller (IC1) can control the output voltage of the buck converter by varying the width of each pulse from zero to 170μs.

The output from pin 7 is connected to two drivers within IC2, here wired in parallel. IC2 is an octal source driver, once used to drive the hammers in old style dot matrix printers (remember them?). This economical chip is suited to our task because it is designed to drive an inductive load and, as an added bonus, includes a diode for our buck converter.

The source driver acts as a switch, so that when its input is high (ie, above 2.4V) the output will be connected to 12V and when the input is low the output will be disconnected. We parallel two drivers to get the maximum possible drive current.

It is the combination of the source driver, its built-in diode, the inductor and the output capacitor that forms the buck converter.

Each output can supply 250mA, which is ample, as a typical fan will draw 120mA. However, if you are connecting


CON1 PC POWER CONNECTOR*
+5V
+12V
10µF 16V
100nF
100nF
20
Vdd
2-PIN SIL HEADERS
SENSOR A INPUT
SENSOR B INPUT
SENSOR C INPUT
SENSOR D INPUT
1.8k
1.8k
1.8k
1.8k
AN0/RA0
AN1/RA1
AN2/RA2
AN3/RA3
OSC1
OSC2
X1 20MHz
22pF
22pF
IC1 PIC18F2550-I/P
+5V
4.7k
100k
MCLR
CON2
USB TYPE B
D–
D+
RC0
Vusb
3.3V
220nF
PIEZO BUZZER
Vss
Vss
LM335Z
ADJ
*MOLEX 8981 SERIES MALE
RC1/CCP2
RC2/CCP1
RB7
RB5
RB3
RB1
RB0
RB2
RB4
RB6
F1 PWM
F2 PWM
TACHO 1b
TACHO 2b
TACHO 3b
TACHO 4b
TACHO 4a
TACHO 3a
TACHO 2a
TACHO 1a
RA5
RA4
RC7
RC6
IC2 UDN2981A
1B 2B 3B 4B 5B 6B 7B 8B
1C 2C 3C 4C 5C 6C 7C 8C
GND
L4 100µH
L3 100µH
L2 100µH
L1 100µH
470µF 25V
4a 4b 3a 3b 2a 2b 1a 1b
8x FAN CONNECTORS
LM335Z
ADJ
2-CORE CABLE
HEADER SOCKET
TEMPERATURE SENSORS AND CONNECTIONS

INTELLIGENT 12V FAN CONTROLLER

Fig.3: the circuit for the *Intelligent 12V Fan Controller* is quite simple given its capabilities. Most of the work is done by the microcontroller (IC1), while IC2 and its associated components form buck converters. There are four variable voltage outputs, one for each pair of fans, making a total of eight fans that can be controlled.

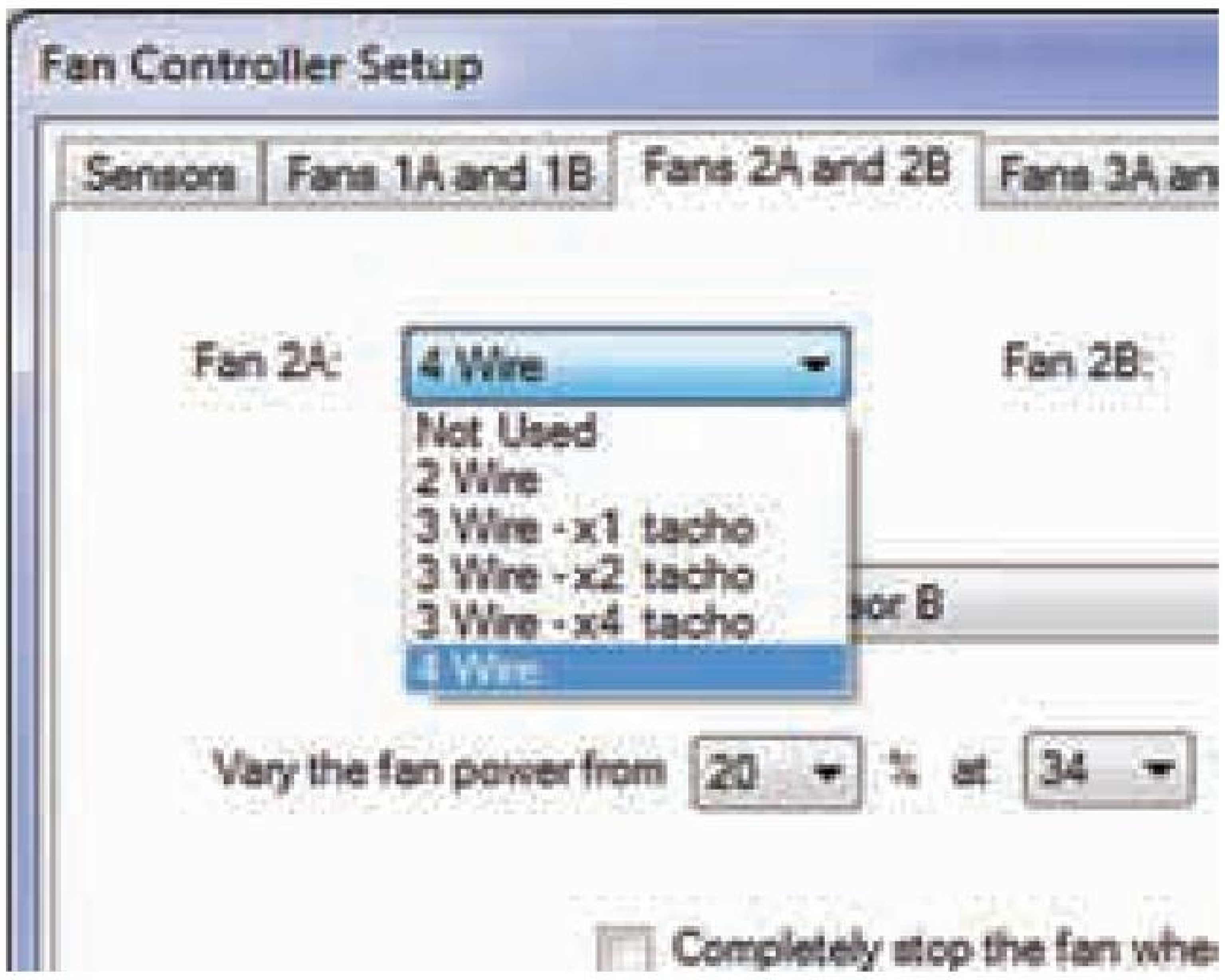


Fig.4: you can configure the controller for five different types of computer fan. The 3-wire fans differ in the number of pulses per revolution produced by the tachometer output. So, for example, the '3-wire – ×2 tacho' should be used with a fan that produces two pulses per revolution. If no fan is connected, the entry should be set to 'Not Used'.

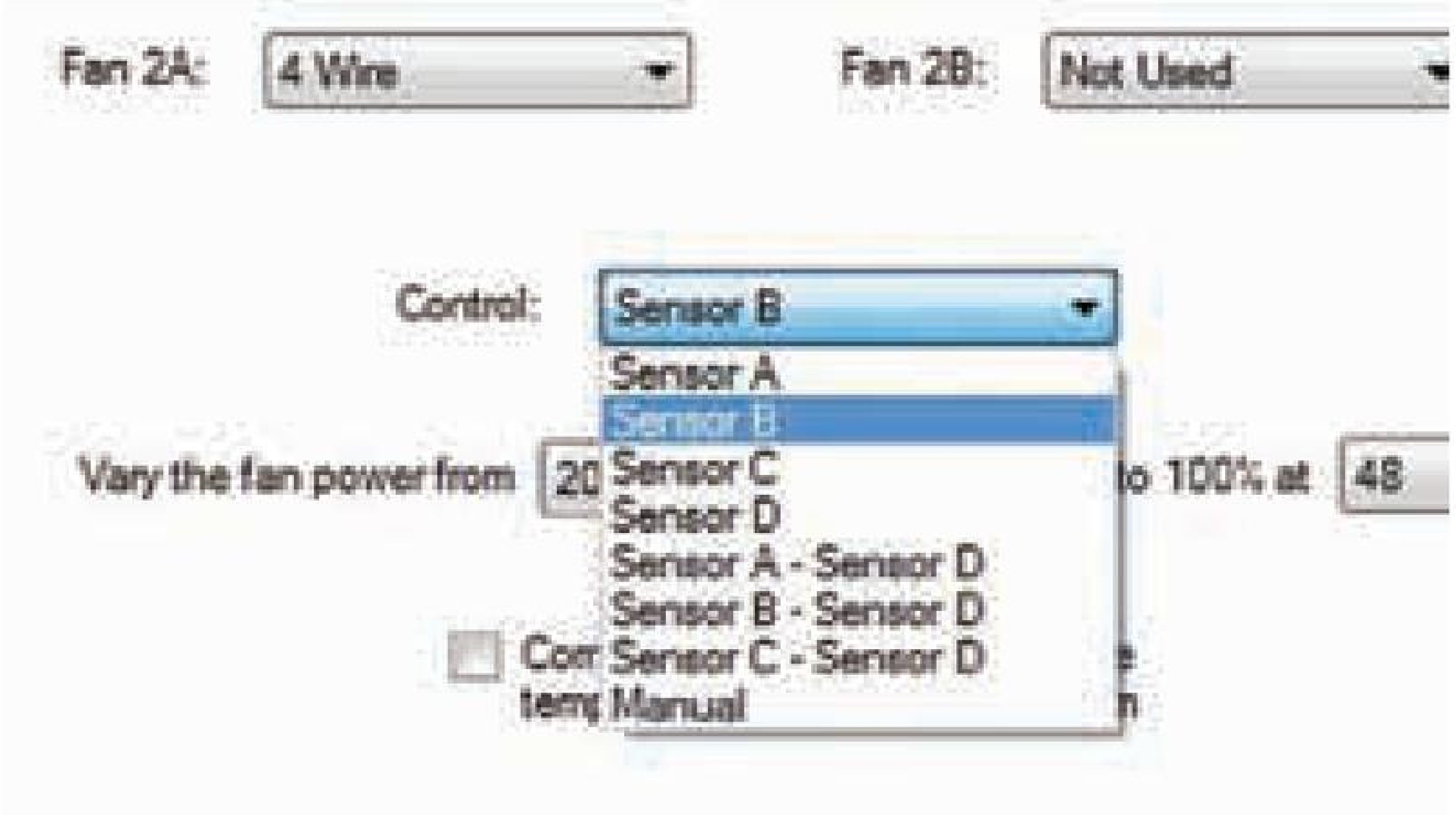


Fig.5: you can select the temperature sensor that will be used to control the speed of each pair of fans. You can also select the difference between a sensor and sensor D for responding to the difference between inlet and outlet temperatures. The 'Manual' entry lets you select a fixed speed for testing.

two fans in parallel as a pair, you should check their total current draw – just to be on the safe side.

The main advantage of a buck converter is that it will deliver a stable DC voltage, while generating little heat. Another method of voltage control would be to use a linear voltage regulator, but that would generate a lot of heat forcing us to use heatsinks and a more complex circuit.

A completely different approach to speed control is to switch the power to the fan rapidly off and on, so that the overall average voltage is low, but this has the side effect of rendering the tachometer output useless. This is because the tachometer signal is generated by electronics within the fan and the pulsed supply voltage messes up the output.

Not so with a buck converter; you get the benefits of low heat generation and a useable tachometer signal.

PWM-controlled fans

The modern 4-wire fans use a pulse-width modulation (PWM) signal to tell the fan what speed to run at. The frequency of this control signal must be 25kHz and a 100% duty cycle tells the fan to run at full speed, while a zero duty cycle will slow or stop the fan.

The *Controller* will support four PWM-controlled fans on the connectors labelled 1A, 1B, 2A and 2B. When the controller is set up for this type of fan it will hold the buck converter output voltage at the maximum and control the speed of the fan by varying the PWM signal from pin 12 and pin13 of IC1.

The connectors for PWM-controlled fans are backwards-compatible with the more common voltage-controlled fans, so you can always plug a 2 or 3-wire fan into these outputs.

Tachometer signal

The tachometer signal from each fan is connected back to the microcontroller (IC1), which uses it to measure the fan's rotational speed. As the fan rotates, it will generate a square wave with the frequency proportional to rotation speed.

This signal is driven by an open-collector output, which means that we need to provide a pull-up resistor so that the fan can pull the line low. This resistor is internal to the microcontroller, and this feature saves us having to use a bunch of external resistors.

The speed of each fan is sent by the microcontroller to the Windows program via the USB interface, and is also used to trigger an alarm if the fan stops. This alarm consists of a one-second 'beep' repeated every minute. The sound is generated by the piezo buzzer connected to pin 11 of IC1.

Progressing around IC1 in a counter-clockwise direction, pins 2, 3, 4 and 5 of the microcontroller are analogue inputs that are used to measure the outputs of the LM335Z temperature sensors. The LM335Z is an easy-to-use device that simply generates a voltage proportional to the temperature. An output of 2.73V represents 0°C and a change of 10mV is equivalent to a 1°C change.

If you verify the temperatures reported by the sensors you might find an error of up to a few degrees. This is a combination of inaccuracy in the LM335Z and variations in the computer's 5V supply, which is used as the reference for measuring the output voltage of the sensor. The error should be small and will be of little consequence in this type of application.

The microcontroller also checks the temperature sensors for a sensible reading, and if any of them are shorted or disconnected it will sound the alarm. As a safety measure, it will also run any fans dependent on the faulty temperature

What is pulse-width modulation (PWM)?

PWM simply means that the signal is a continuous string of pulses at a fixed frequency. By varying the ratio of the pulse width to the gap between the pulses we can vary the speed of a fan.

This ratio is called the 'duty cycle'. When it is high (approaching 100%) the pulses will be wide and the fan will run at full speed. A low duty cycle (narrow pulses) will cause the fan to spin slowly.

sensor at full speed until the fault is corrected.

The firmware running in the microcontroller is designed to be stable, but there may be a case where it has been set to an 'impossible' configuration. To correct this, you can reset the micro to its initial default condition by temporarily placing a wire shorting link across the connector pins for Sensor A, while you apply power to the circuit.

Continuing around IC1, the crystal connected to pin 9 and pin 10 provides the main clock to the microcontroller, while the USB interface is connected to pins 1, 15 and 16. Pin 1 is used by the microcontroller to sense when the controller is plugged into a USB host, so that it can commence communication.

The capacitor on pin 14 provides smoothing for the internal 3.3V supply used by the USB interface.

Power is supplied by a standard 4-pin Molex connector of the type used with ATA hard disks and CD/DVD drives. Most computers have plenty of these connectors, so finding power should not be a problem.

The *Controller* uses two completely separate ground systems, one for the 5V components (IC1 and USB) and the other for the 12V components (IC2 and the fans). These are connected to separate ground pins on the power connector and only meet somewhere inside the computer's power supply. This reduces the effects of current spikes in the buck converters, which could interfere with the operation of the microcontroller.

Software application

With a device like this you always have the challenge of how to set the various operating parameters. We could have used a large number of DIP switches, but as the controller will be mounted in a computer, we thought 'why not give it a USB interface and modern software for the setup?'

The *Intelligent 12V Fan Controller* implements a serial interface over USB, and it appears on your computer as a communications or COM port. This means that it is easy to send and receive commands to/from the controller (see the box 'Communicating with the Fan Controller').

To get started, you need to install 'Silicon Chip USB Serial Port Driver.zip', available from the *EPE* website. This driver was also used in the *GPS*

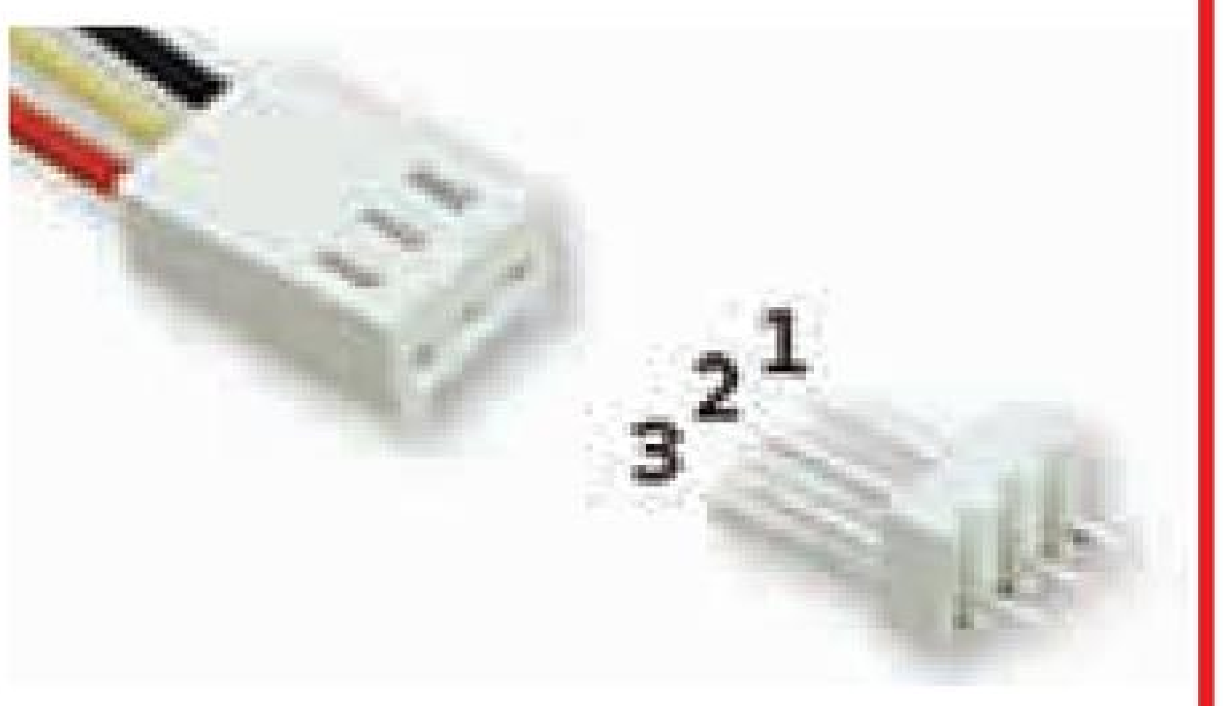
Know your fans

Most fans in today's computers are powered by a 12V brushless DC motor that typically draws 100mA to 130mA. Brushless simply means that the DC voltage is commutated electronically.

You can expect to see three different types of fans:

2-wire fans

As the name suggests, this type of fan has just two wires. The connector type varies, but normally it will be a 3-pin header plug with pin 1 being the ground, pin 2 the +12V supply and pin 3 vacant. By varying the supply voltage you can vary the speed of the fan.



3-wire fans

These are the same as 2-wire fans, but with the addition of a tachometer output, which is connected to pin 3 (vacant in a 2-wire fan).

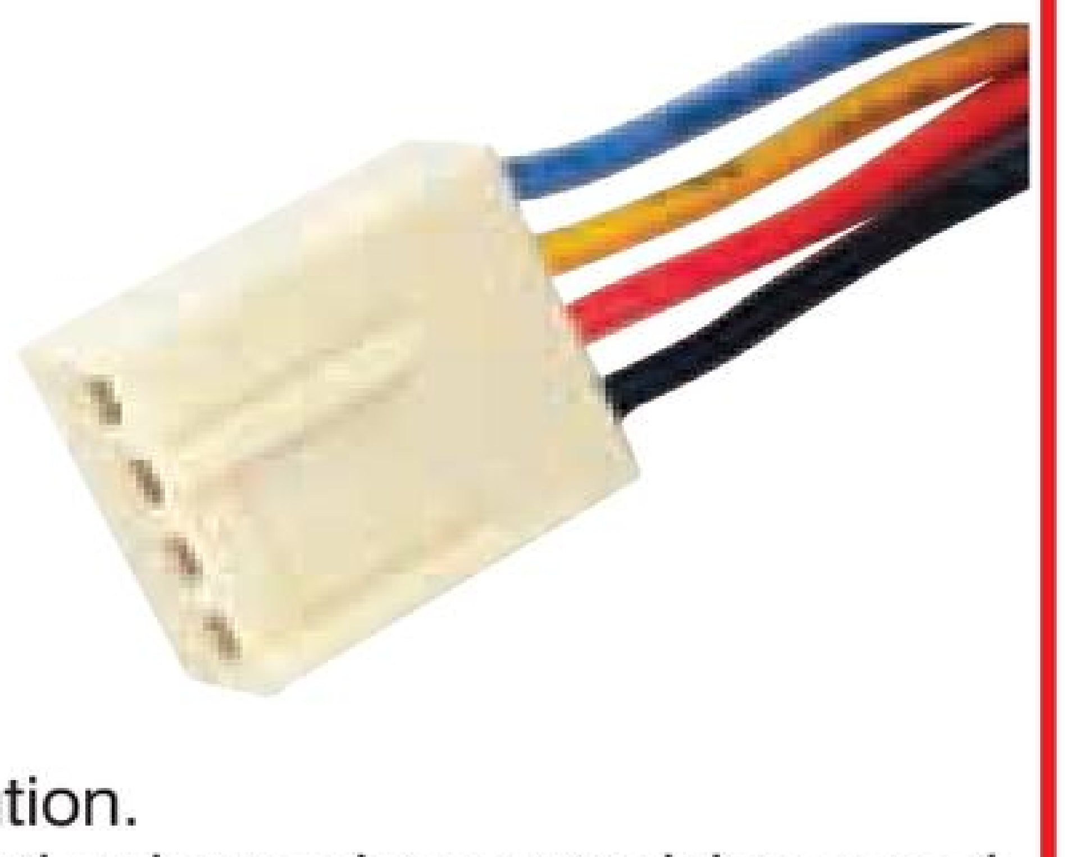
Unfortunately, there is little standardisation on the tachometer output. Most fans generate two pulses per revolution, but some fans generate one or four pulse(s) per revolution. For this reason, the setup program will let you configure three different types of 3-wire fans with one, two or four pulses per revolution.

If you do not know the specifications of your fan's tachometer you should select an entry that results in approximately 3000 RPM at full speed, as this is the typical top speed of most computer fans.

4-wire fans

The 4-wire standard was recently developed by Intel and is mostly used for the fans that Intel and AMD provide with their high performance CPUs. Otherwise, they are still quite rare.

The standard uses a 4-pin connector which is designed to be compatible with the 3-pin connectors used for 3-wire fans – so pins 1, 2 and 3 are the normal ground, power and tachometer output. Thankfully, the tachometer output is standardised at two pulses per revolution.



Pin 4 is a pulse-width modulated (PWM) input that is used to control the speed of the fan. A 100% duty cycle (voltage mostly high) will make the fan run at full speed, while a zero duty cycle (no pulses or zero volts) will stop the fan.

Despite this, most 4-wire fans will not let you completely stop the fan; the minimum they will run at is generally 20% of full speed.

The connector is a special type (see the illustration above) that allows it to be plugged into a 3-pin plug. In this case, the fan will act as a standard 3-wire fan and can be controlled by varying the supply voltage.

A 4-wire fan works best when it is controlled by the PWM input; so, if you have this type of fan, it should be plugged into the sockets for fans 1A, 1B, 2A or 2B which fully support the Intel 4-wire fan specification.

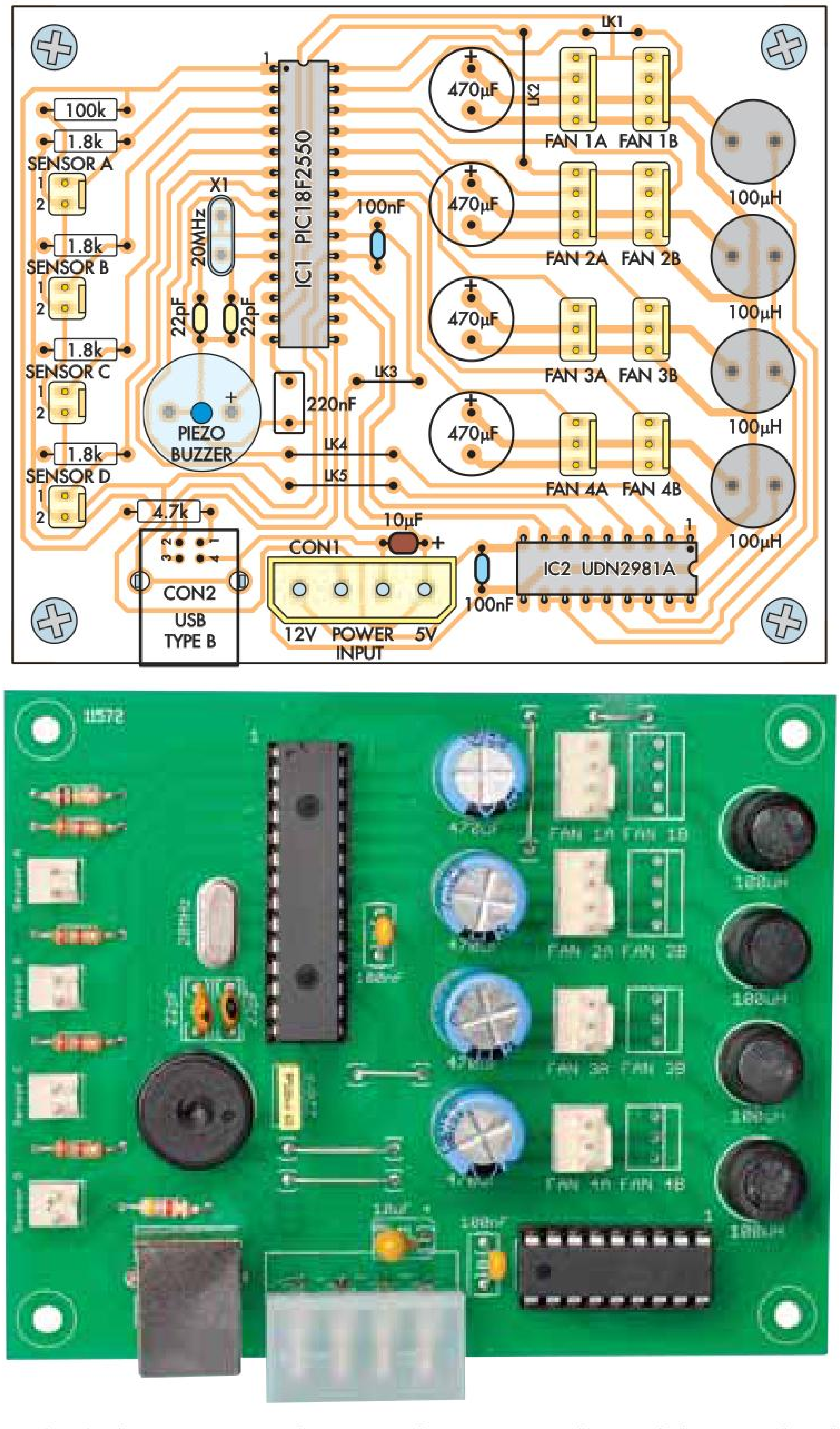


Fig.6 (top): the component layout with same-size photo of the completed PC board underneath. As explained in the text, you only need to include the output components for the number of fans you wish to control.

Car Computer (January 2012) so, if you have already installed it for that project, you will not have to install it again. Regardless, full instructions are included with the device driver and it is not hard to install.

The Windows program can also be downloaded from the *EPE* website and installed by running the Setup program. When you do this, you should be connected to the Internet, as the installation package will also need to download some components of the .NET framework from the Microsoft website to complete the installation.

This program is written in Microsoft's VB Express 2008, which is a free development environment provided by Microsoft. The source code will also be available for download from the *EPE* website, so you can, if you wish, modify and recompile the program to suit your own needs at no cost.

The source code for the firmware running on the microcontroller is also available from the website, and is also built using a free development environment, in this case, Microchip's C18 Student Edition (or 'Lite') compiler and the MPLAB development environment. So you can modify this too if you wish.

The device driver, the Windows program and both development environments will work with all modern versions of Windows (XP, Vista and Windows 7) in both 32 and 64-bit modes.

When you first run the Windows program you will be presented with a blank window and you need to set the COM port for the *Intelligent Fan Controller* by selecting Setup -> Communications Port. To discover what port the controller is on you could try the listed COM ports at random (the software will tell you if it has found the *Intelligent Fan Controller*) or you could use Device Manager to identity which COM port number was allocated to the Fan Controller.

Once the port number has been set, the software will remember the number and automatically use that to establish communications the next time the program is started.

When communications have been established, the program will display the temperatures and fan speeds measured by the *Intelligent Fan Controller*. It will also download the current configuration settings from the controller, and you can change these by selecting Setup -> Fans and Sensors…

Changing the settings

In the setup window, you can select what temperature sensors are installed, and the detailed configuration for each pair of fans. Fig.4 shows a drop-down list of the types of fans that can be connected. As you can see, the 3-wire fans come in three different types depending on the number of pulses per revolution produced by the tachometer.

Fig.5 shows the choices that you have for selecting the temperature sensor. These include any one of the four sensors, or the difference between two sensors. Control of the fan's speed is made by adjusting the speed based on the temperature measured by the sensor. Fig.2 shows the detail of this setup section.

The minimum power for a fan is determined by the lowest speed that it can dependably run at. To determine this speed, select manual control and progressively increase the power setting until the fan starts spinning. Then add a 10% safety margin – eg, if the fan starts spinning at 25%, set the minimum to 35%.

In most cases, you will want to leave the fan spinning at its minimum speed even when the temperature is cool, to ensure that there is always some circulation of air within the computer's case. However, by ticking the box under the temperature settings, you can instruct the controller to completely stop the fan when the temperature is low. A fan that is stationary is a very silent fan!

When the Controller needs to start a fan that has been stopped, it will run it for a few seconds at near full speed before it drops the power down to the minimum specified in the setup window. The same happens when power is first applied to the *Controller*. This brief spin up ensures that a fan is not stuck in the stopped condition.

Any changes that you make to the setup are copied to the microcontroller in the *Intelligent Fan Controller*, which saves them in its non-volatile memory. This means that you can disconnect the USB cable, and even uninstall the Windows program and it will not affect the operation of the *Controller*. This feature can also be used to set up the *Intelligent Fan Controller* for another computer that does not have a USB port.

Construction

Construction of the *Intelligent 12V Fan Controller* is straightforward. All components sit on a single PC board measuring 80mm × 100mm, which is coded 857. This board is available from the *EPE PCB Service*. The component overlay is shown in Fig.6.

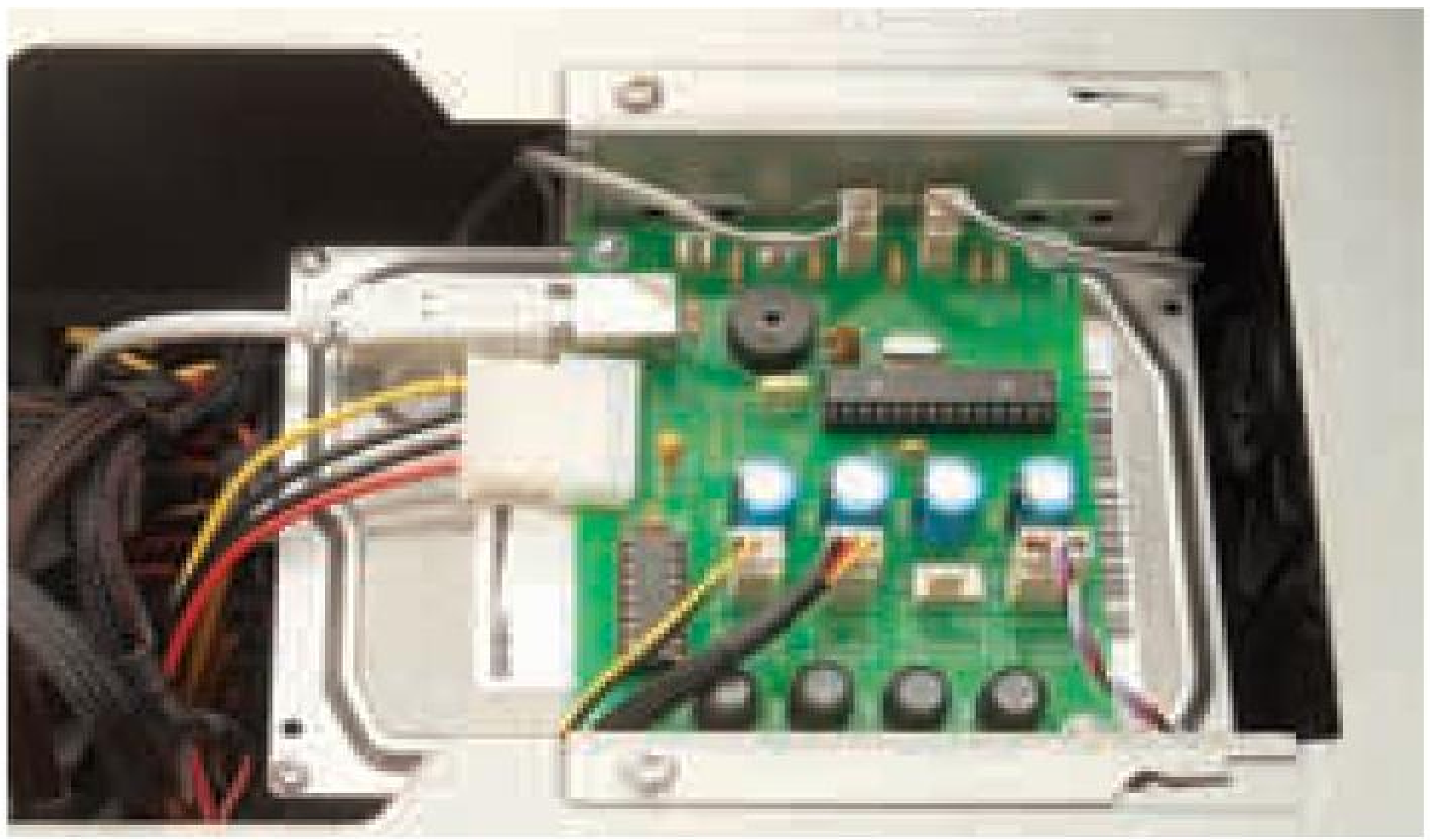
The PIC18F2550 I/SP microcontroller needs to be programmed with the hex file that will be available on the *EPE* website. You should use IC sockets for both IC1 and IC2, as this will make it easier to do any fault-finding.

The inductors are high frequency chokes with a current rating of 1A or more. We used single-ended 'barrel style' chokes, but the board will also accept the more common type of chokes wound on a toroid (or ring) core.

The 4-pin header connectors need a little explanation. The Intel standard for 4-wire fans specifies that the connector should have a narrow tongue, which is the width of three pins (see Fig.7). This will allow you to plug in either a 3-wire fan using a 3-pin plug or a 4-wire fan using a 4-pin plug.

Four-wire connectors for a PC board are harder to find than the proverbial 'hen's teeth', so you will have to make your own from a normal 4-pin PC board connector by using a sharp knife to cut away 3mm of the plastic tongue behind pin 4. Fig. 7 shows what the connectors should look like.

On our prototype we only populated the first line of fan connectors (1A, 2A, etc) as we were unlikely to have more than four fans in our computers. You can also vary the components used. For example, if you were only going to use three fans, you could omit the components (inductor, capacitor, etc) associated with fans 4A and 4B.



We mounted the Intelligent Fan Controller in a spare 3½-inch drive bay, but there are many other places that you can mount it. You may need to fabricate a mounting bracket or use screws and spacers to keep it secure.

Parts List – Intelligent 12V Fan Controller

1 PC board, code 857, available from the *EPE PCB Service*, size, 100mm × 80mm
1 20MHz crystal
4 100µH HF choke (1A or higher rating) (Jaycar LF-1272)
1 mini buzzer, PCB mounting (Jaycar AB-3459)
1 4-pin disk drive power socket (Jaycar PP-0744)
1 USB type-B socket, PCB mount (CON2)
1 28-pin IC socket (0.3" pitch)
1 18-pin IC socket
4 2-pin header plug
4 2-pin header connector, PCB mount
4 3-pin header connector, PCB mount
4 4-pin header connector, PCB mount
Figure-8 (two core) flexible wire 100mm 0.7mm tinned copper wire (for links)

Semiconductors
1 PIC18F2550-I/SP programmed microcontroller (IC1)
1 UDN2981A octal source driver (IC2)
4 LM335Z temperature sensor
All are available from:
www.futurlec.com or **www.farnell.com.au**

Capacitors
4 470µF 25V radial electrolytic
1 10µF 16V tantalum
1 220nF MKT
2 100nF monolithic
2 22pF ceramic

WE DO NOT SUPPLY READY-PROGRAMMED MICROCONTROLLERS

Resistors (0.25W 5%)
1 100kΩ 1 4.7kΩ 4 1.8kΩ

Similarly, if you only need two temperature sensors you can make up just two sensor cable assemblies and leave out the connector and resistor associated with Sensors C and D.

Each temperature sensor consists of an LM335Z sensor on one end of a length of lightweight figure-8 (two core) cable and a 2-pin header plug on the other end. You need to cut off the temperature compensation pin on the LM335Z, as that is not needed, and solder the wires to the remaining pins. Polarity is important, so follow the diagram in Fig. 9. Before you solder the joints, slide heatshrink tubing onto the wires and shrink it over the joints after you have completed the soldering. This will insulate the joints and provide a neat finish.

Installation

We installed the *Intelligent Fan Controller* in a vacant 3½-inch drive bay, but it could be situated almost anywhere inside your computer. Depending on the chosen location, you will probably need to make up a mounting bracket or use screws and spacers to hold the PC board securely.

Ideally, the LM335Z temperature sensor should be placed near the area that the associated fan will be ventilating. For example, if you have a fan mounted in the top of the case, the associated temperature sensor should also be in the top part of the case. If you want to keep it simple, you can

Communicating with the Intelligent Fan Controller

The details for sending commands and receiving data from the *Intelligent 12V Fan Controller* are included in the source code which can be downloaded from the *EPE* website. The following is a summary to give you the flavour of how it works.

The *Intelligent Fan Controller* implements a serial interface over USB, and every second it sends on this interface a string which looks like: FCD,42,45,40,38,40,40,40,40…

The letters FCD form an identifying signature, which is followed by 16 comma separated numbers. The first four are the measured temperatures (in °C), the next four are the output from the buck converters (in the range of 0 to 100) and the last eight are the speed of each fan in RPM.

You can set the various parameters of the *Intelligent Fan Controller* by sending a command that starts with FCS, followed by a sequence of comma-separated numbers which are the new settings.

You can also query the controller for its current settings with the command FCQ and you will receive back a string that starts with FCR followed by the current settings.

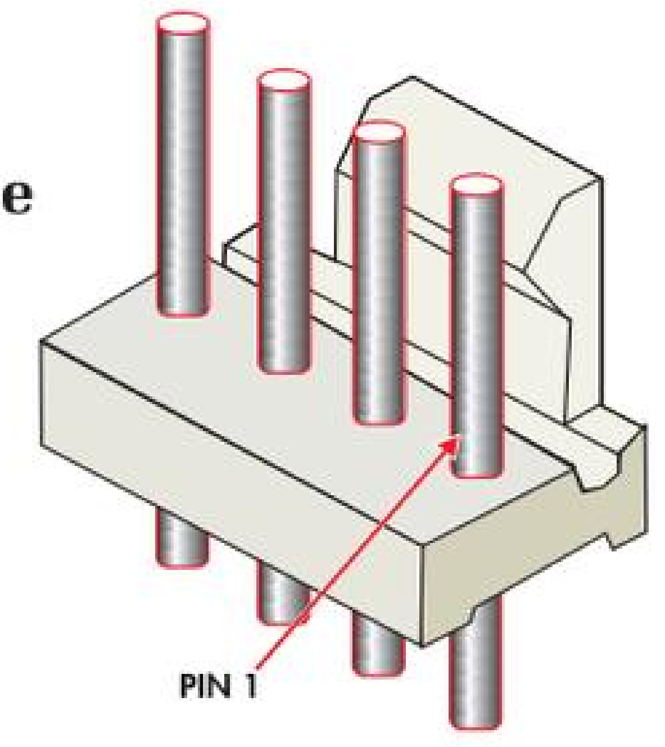
All these commands are simple strings of ASCII characters. So, if you don't like the software that we have written, you can easily write your own program or use batch/shell scripts to interact with the *Intelligent Fan Controller*.

also control a number of fans with a single sensor mounted somewhere centrally in the case.

The *Intelligent Fan Controller* is designed mainly for controlling general case fans, but it can also be used to control the fans on your graphics card, power supply and/or CPU.

In the case of a graphics card or CPU, each should have a dedicated temperature sensor that is clamped directly to the heatsink, with some thermally conductive paste between the sensor and heatsink. This is because the temperature in a graphics card or CPU can rise rapidly depending on the processing load, therefore a good thermal connection for the sensor will ensure that the *Intelligent Fan Controller* can respond quickly. You should also set the minimum speed of the fan to be reasonably fast (say 35%) so that there will always be some air passing over the heatsink.

Fig.7 (right): the four-pin connector for fans 1A, 1B, 2A and 2B need 3mm of the locating tongue behind pin 4 to be trimmed, as shown in this diagram (and below). This will allow either a 4-wire or a 3-wire fan to be plugged on to the connector.



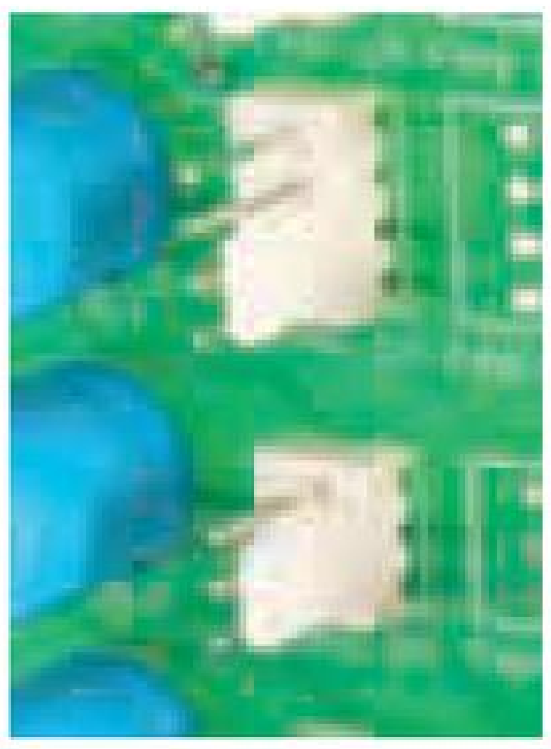
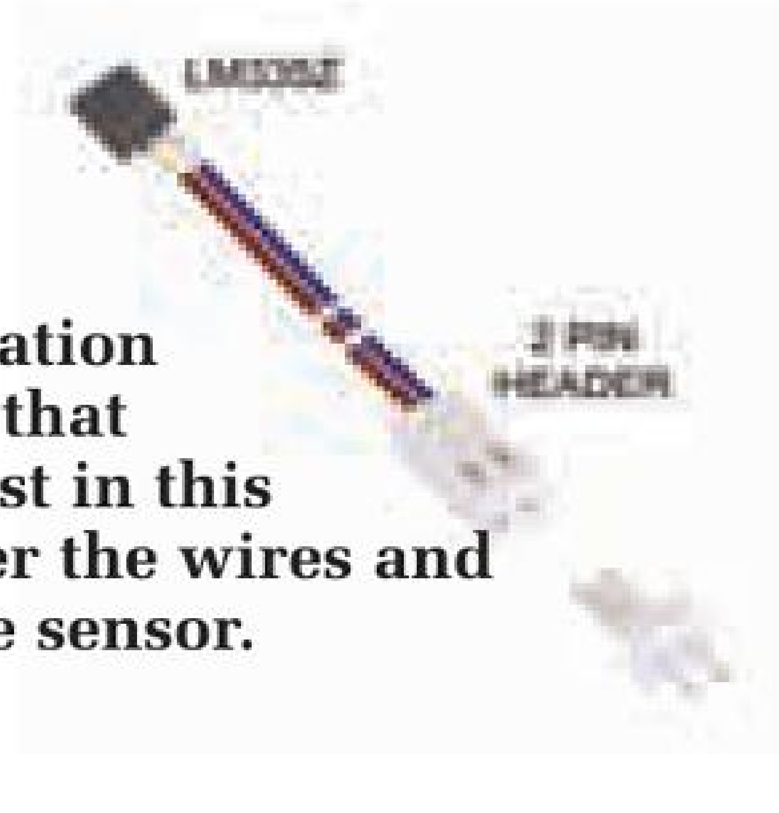


Fig.8 (left): this shows our home-made 4-wire connector (labelled FAN 2A) and a standard 3 wire connector (labelled FAN 3A). When you trim the plastic tongue on the 4-wire connector you need to make sure that a 3-pin plug can be fitted on to pins 1, 2 and 3 of the connector, while leaving pin 4 free.

Fig.9: wiring diagram for the temperature sensor, cable and connector. The left-hand pin of the LM335Z is the temperature compensation pin and should be trimmed off. Note that the flat side of the sensor is uppermost in this diagram. Slide heatshrink tubing over the wires and shrink over the soldered joints on the sensor.



If the fan you wish to control is inside the computer power supply, *it must be approached with caution*. Many of the components in these devices sit at the full 230V mains potential and, if you are not careful, you could run the risk of electrocution or fire. Never open the computer power supply case without disconnecting the mains plug (usually an IEC connector); in fact, we caution against opening up the power supply unless you thoroughly know what you are doing and have had prior experience with this type of device.

The safety-first adage 'if in doubt, don't' is never more applicable than inside computer power supplies.

To control the speed of a fan in a power supply, the best approach is to run the fan leads directly out of the power supply through a convenient hole in its cover. The leads must be firmly secured away from the other circuitry in the power supply so that they will not move around after you replace the cover.

The power supply should also have its own dedicated temperature sensor and, for safety reasons, this should be mounted outside of the case in the exhaust airflow from the power supply. The fan should be configured to keep slowly spinning, even at cold temperatures, so that the sensor can detect a temperature rise in the air exiting the power supply.

Fault finding

The firmware of the *Intelligent Fan Controller* has a default setup which assumes four 2-wire fans (1A, 2A, 3A and 4A) controlled by Sensor A. So, as a first test, you can simply connect the controller to +5V and after five seconds you should hear a beep from the piezo buzzer, indicating that it has detected a faulty sensor (because Sensor A is not plugged in). This tells you that the microcontroller (IC1) and its firmware are running OK.

As a more extensive test, you should connect the controller via USB to your computer, load the driver and Windows program, and experiment with changing the settings of the controller. If you cannot get this working you should check the driver installation, as this is the most likely failure point.

If the *Intelligent Fan Controller* does not respond to either of these tests, you should check that there is 5V between pin 19 and pin 20 of IC1. Also check for 12V between pin 9 and pin 10 of IC2. If you have an oscilloscope, check for a 20MHz signal on pin 9 and pin 10 of IC1. This is the main clock for the micro, and if it is not there, nothing will work.

If the microcontroller is working and you have trouble with driving a fan you should check the buck converter circuit. There should be a string of pulses from the micro and also at the output of IC2 and finally, a voltage on the associated capacitor.

So that's it. Now all you need to do is build your own *Intelligent 12V Fan Controller* and you too can sit back and enjoy the 'sound of silence' from your computer! For *errata*, notes and new firmware related to the *Intelligent Fan Controller,* go to **http://geoffg.net/fancontroller.html.** ***EPE***

Reproduced by arrangement
with SILICON CHIP
magazine 2012.
www.siliconchip.com.au

CRICKLEWOOD ELECTRONICS
Established 1981

Frustrated with your supplier?
Visit our component packed
website for a vast range of
parts - old and new,
many unavailable elsewhere!
www.cricklewoodelectronics.com

1000's OF PRICES REDUCED!

Alternatively phone us on
020 8452 0161 with your
requirements.

Visit our Shop, Call or Buy online at:
www.cricklewoodelectronics.com
020 8452 0161 Visit our shop at:
40-42 Cricklewood Broadway
London NW2 3ET

SHERWOOD ELECTRONICS

Buy 10 x £1 Special Packs and choose another one FREE

SP1	15 x 5mm Red Leds
SP2	12 x 5mm Green Leds
SP3	12 x 5mm Yellow Leds
SP5	20 x 5mm 1 part Led clips
SP6	15 x 3mm Red Leds
SP7	12 x 3mm Green Leds
SP8	10 x 3mm Yellow Leds
SP9	20 x 3mm 1 part Led clips
SP10	100 x 1N4148 diodes
SP11	30 x 1N4001 diodes
SP12	30 x 1N4002 diodes
SP18	20 x BC182B transistors
SP20	20 x BC184B transistors
SP23	20 x BC549B transistors
SP24	4 x Cmos 4001
SP25	4 x 555 timers
SP26	4 x 741 Op-amps
SP28	4 x Cmos 4011
SP29	4 x Cmos 4013
SP33	4 x Cmos 4081
SP34	20 x 1N914 diodes
SP36	25 x 10/25V radial elect caps
SP37	12 x 100/35V radial elect caps
SP38	15 x 47/25V radial elect caps
SP39	10 x 470/16V radial elect caps
SP40	15 x BC237 transistors
SP41	20 x Mixed transistors
SP42	200 x Mixed 0.25W CF resistors
SP47	5 x Min. PB switches
SP49	4 x 4 metres stranded core wire
SP102	20 x 8 pin DIL sockets
SP103	15 x 14 pin DIL sockets
SP104	15 x 16 pin DIL sockets
SP109	15 x BC557B transistors
SP112	4 x Cmos 4093
SP115	3 x 10mm Red Leds
SP116	3 x 10mm Green Leds
SP118	2 x Cmos 4047
SP124	20 x Assorted ceramic disc caps
SP130	100 x Mixed 0.5W CF resistors
SP131	2 x TL071 Op-amps
SP133	20 x 1N4004 diodes
SP134	15 x 1N4007 diodes
SP135	5 x Miniature slide switches
SP137	4 x W005 1.5A bridge rectifiers
SP138	20 x 2.2/63V radial elect caps
SP142	2 x Cmos 4017
SP143	5 Pairs min. croc.clips (Red+Blk)
SP144	5 Pairs min. croc. clips (assorted colours)
SP146	10 x 2N3704 transistors
SP151	4 x 8mm Red Leds
SP152	4 x 8mm Green Leds
SP153	4 x 8mm Yellow Leds
SP154	15 x BC548B transistors
SP155	6 x 1000/16V radial elect. caps
SP160	10 x 2N3904 transistors
SP161	10 x 2N3906 transistors
SP164	2 x C106D thyristors
SP165	2 x LF351 Op-amps
SP166	20 x 1N4003 diodes
SP167	5 x BC107 transistors
SP168	5 x BC108 transistors
SP172	3 x Standard slide switches
SP173	10 x 220/25V radial elect caps
SP174	20 x 22/25V radial elect caps
SP175	20 x 1/63V radial elect caps
SP177	8 x 1A 20mm quick blow fuses
SP178	8 x 2A 20mm quick blow fuses
SP181	5 x Phono plugs – assorted colours
SP182	20 x 4.7/63V radial elect caps
SP183	20 x BC547B transistors
SP186	6 x 1M horizontal trimpots
SP189	4 x 4 metres solid core wire
SP192	3 x Cmos 4066
SP195	3 x 10mm Yellow Leds
SP197	6 x 20 pin DIL sockets
SP198	5 x 24 pin DIL sockets
SP199	4 x 2.5mm mono jack plugs
SP200	4 x 2.5mm mono jack sockets

RESISTOR PACKS – C.Film

RP3	5 each value - total 365 - 0.25W	£3.65
RP7	10 each value - total 730 - 0.25W	£4.95
RP10	1000 popular values - 0.25W	£7.00
RP4	5 each value – total 305 - 0.5W	£4.65
RP8	10 each value - total 610 - 0.5W	£7.40
RP11	1000 popular values - 0.5W	£10.15

Catalogue £1.25 inc. P&P or
FREE with first order.
P&P £2.50 per order. NO VAT
Cheques and Postal Orders to:
Sherwood Electronics,
10 NEWSTEAD STREET,
MANSFIELD, NOTTS.
NG19 6JJ

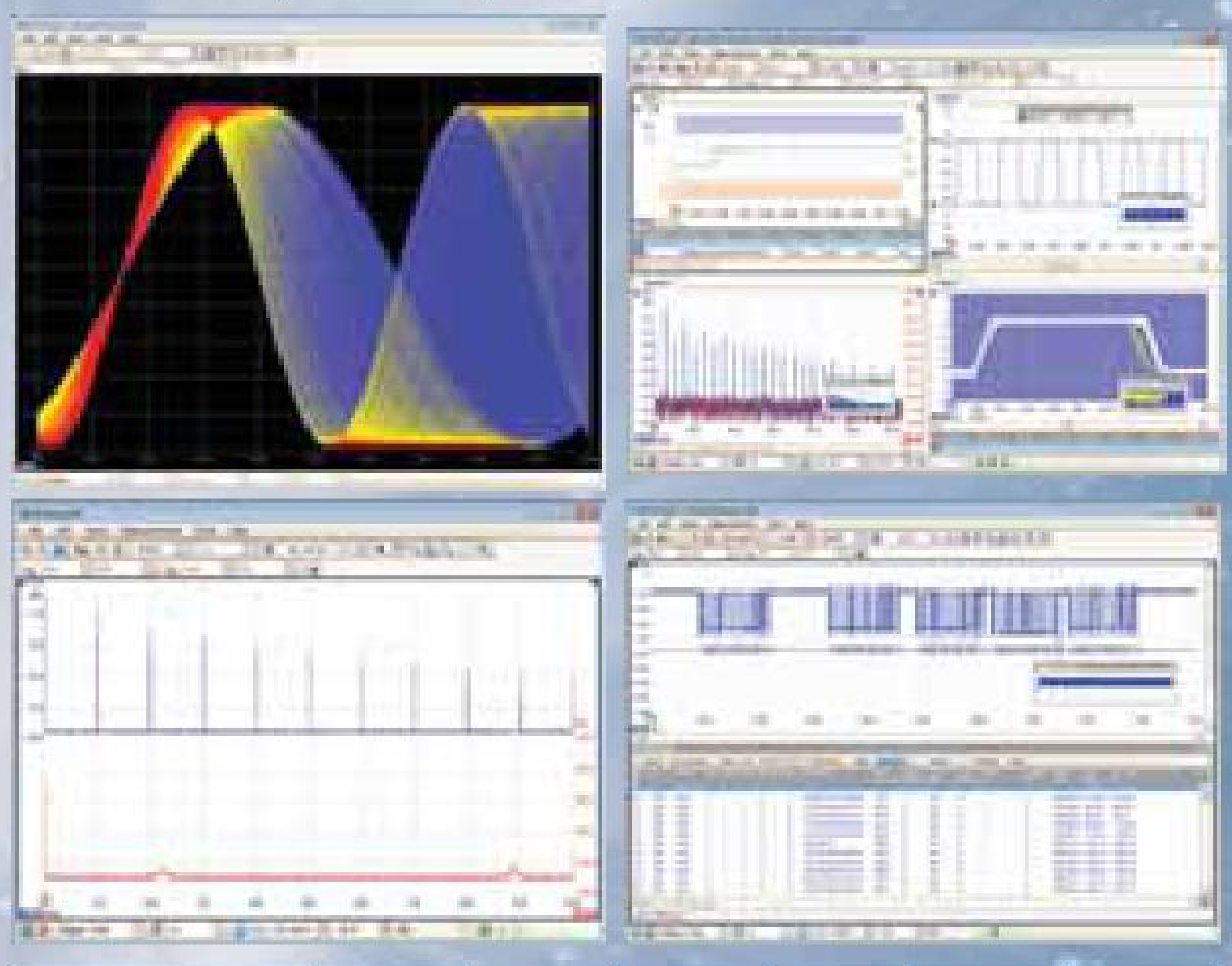
pico Technology

GET MORE WITH THE
CLASS LEADING OSCILLOSCOPES

PicoScope 6000 Series

MORE MODELS • MORE CHOICE
MORE FEATURES AS STANDARD

Highest sampling rate and deepest
memory of any scope for this budget

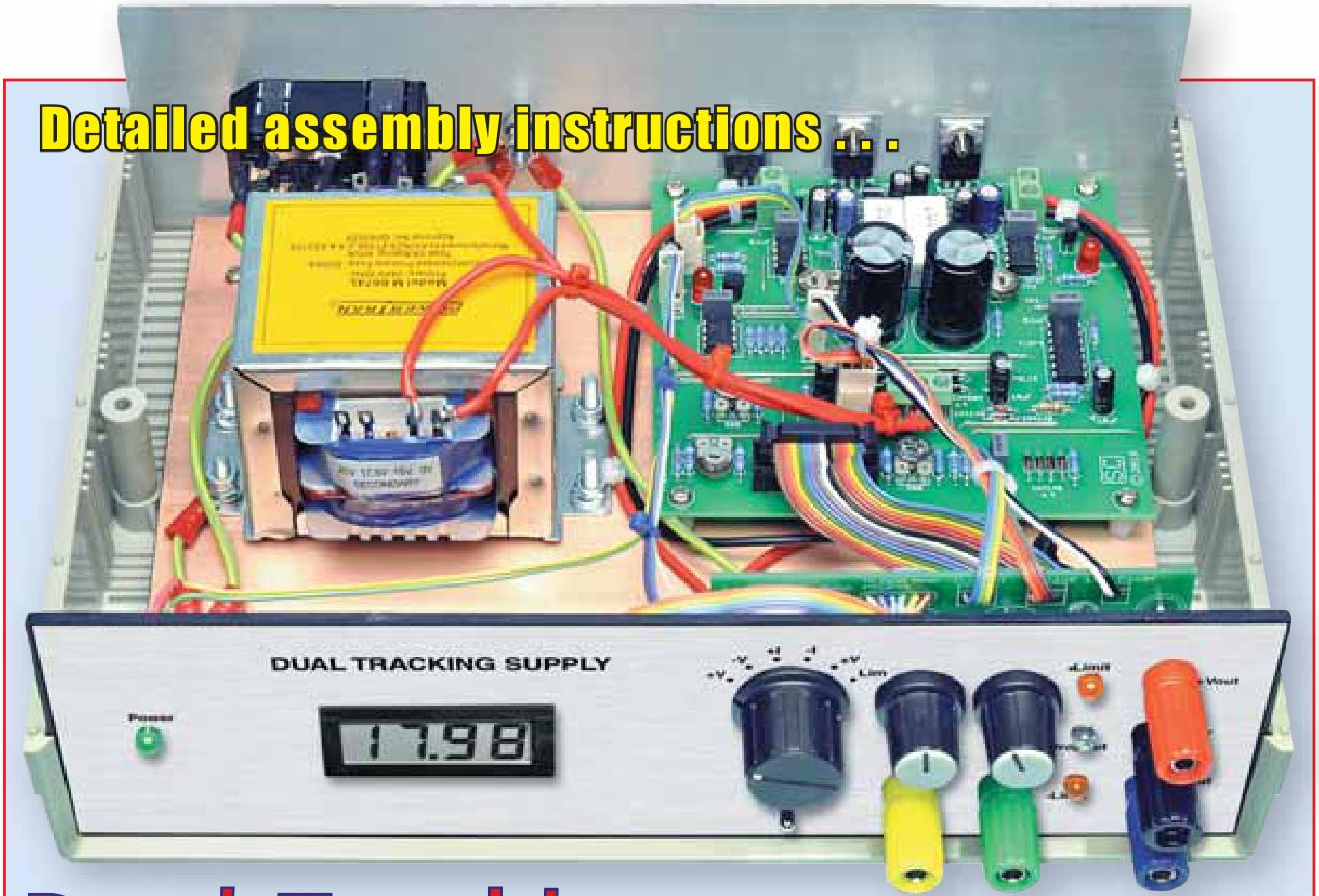


	6402A	6402B	6403A	6403B	6404A	6404B
Channels	4					
Bandwidth	250 MHz		350 MHz		500 MHz	
Sampling Rate	5 GS/s					
AWG or Function Generator	FG	AWG	FG	AWG	FG	AWG
Memory	128 MS	256 MS	256 MS	512 MS	512 MS	1 GS
Price (ex. VAT)	£1995	£2495	£2995	£3495	£3995	£4495

ALL MODELS INCLUDE PROBES, CARRY CASE, FULL SOFTWARE AND 5 YEAR WARRANTY. SOFTWARE INCLUDES. MEASUREMENTS, SPECTRUM ANALYZER, FULL SDK, ADVANCED TRIGGERS, COLOR PERSISTENCE, SERIAL DECODING (CAN, LIN, RS232, I²C, SPI), MASKS, MATH CHANNELS, ALL AS STANDARD. FREE UPDATES.

www.picotech.com/PS150

Detailed assembly instructions . . .



Dual Tracking ±0V to 19V Power Supply

Part 2: By NICHOLAS VINEN

Last month, we introduced our new Dual Tracking ±19V Power Supply and explained how it works. This month, we show you how to assemble the PC boards, install them in a case, wire it up and get it going. Both the mains-powered and plugpack-powered versions are covered.

AS MENTIONED last month, there are two versions of this supply – one powered via an internal mains transformer, and the other via an external AC plugpack. These instructions concentrate on the mains-powered version, which can supply more output current. If you want to build the plugpack version, check the blue panel near the end of the article.

Main board assembly

Fig.8 shows the parts layout on the main PC board (code 851). All PC boards for this project are available from the *EPE PCB Service*.

Start construction by carefully inspecting the underside of the board for any cracks in the copper tracks, or short circuits. That done, install the 20 wire links using 0.71mm tinned copper wire. You can substitute 0Ω resistors for some of the shorter links if you prefer, although none have been specified in the parts list.

Once the links have been installed, mount the six 1N4148 small-signal diodes (D11, D12 and D13 to D16). Note that D11 and D12 face in opposite directions.

Next, solder in all the 0.25W resistors. If you are building the plugpack version, don't forget to install a 150kΩ resistor instead of the 91kΩ resistor to reduce the current limit appropriately. Check each resistor with a digital multimeter (DMM) before installing it, since the colour codes can sometimes be difficult to read.

Follow with the ten 1N4004 power diodes (D1 to D10). Six of these have a short lead spacing (0.3-inch or 7.62mm), so their leads must be bent right at the diode bodies, ensuring they sit flat on the board. After that, solder the TVS (or the alternative 5W Zener diode) into place. Leave some space between it and the board surface (about 3mm), as it will get very hot if the 5V output is shorted for more than a couple of seconds.

Now you can install the four DIP ICs. Make sure they go in the right way around – see Fig.8. Sockets have not been specified, but can be used if desired. After the ICs, mount the five trimpots. Regular horizontal or Piher-style mini trimpots can be used. They all have the same value and can only go in one way.

Next on the list are the BC549 and BC559 transistors (Q1 and Q2) and the 78L15 and 79L15 regulators (REG3 and REG4). These are all in TO-92 plastic packages, so check their markings carefully to ensure they each go in the correct position. Be sure to orient them as shown in Fig.8, and use small pliers to bend their leads if necessary, so that they fit the PC board holes.

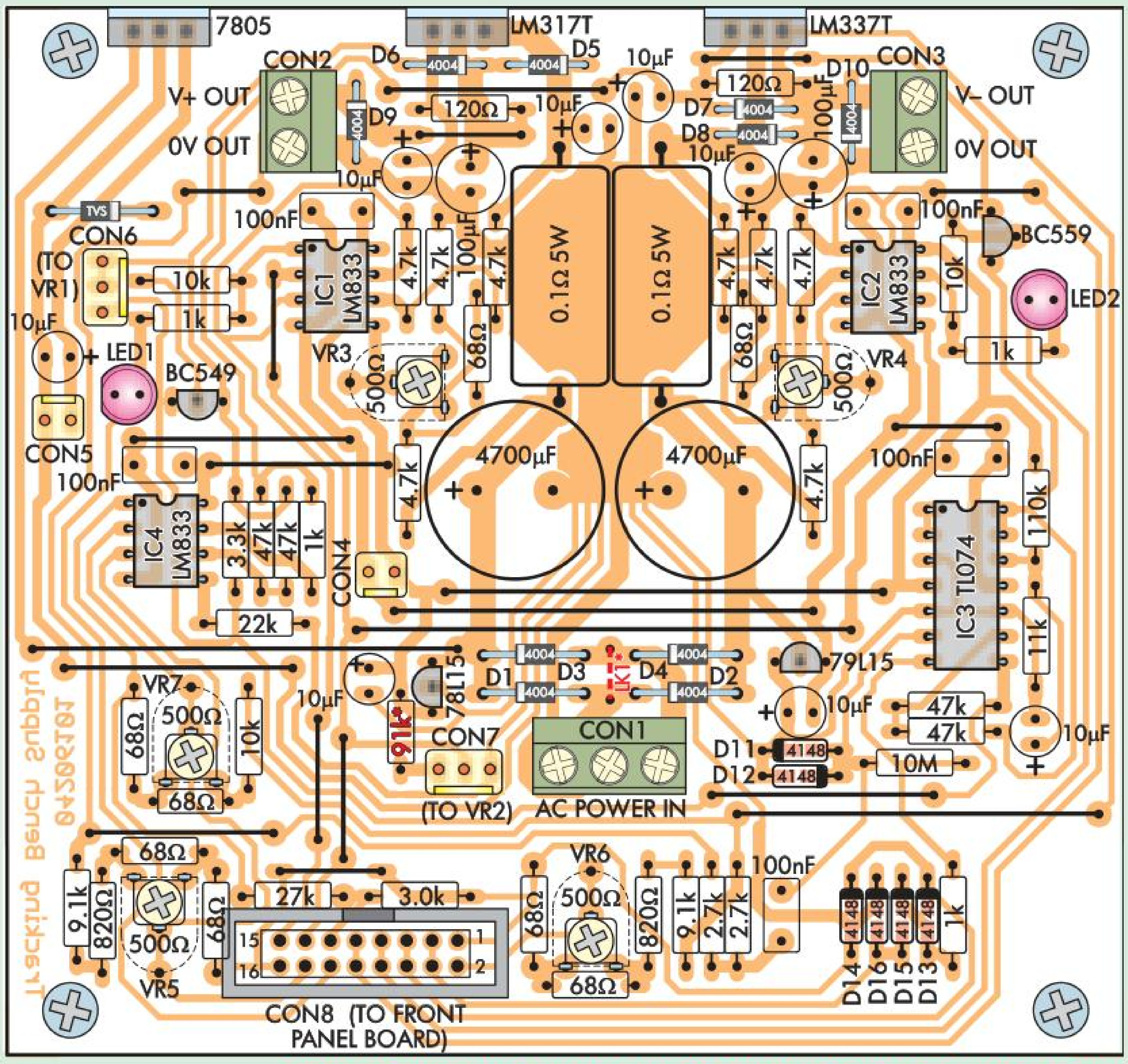
Once they're in, install the five 100nF MKT capacitors, then solder the 16-pin IDC socket (CON8) in place. Line up the notch in the socket as shown on the overlay (ie, towards the top), and check that the socket is sitting flat against the PC board before soldering its pins.

LED1 and LED2 can now go in (they are oriented in opposite directions), followed by the three screw terminal blocks (CON1 to CON3). Be sure to install the latter with their entry holes facing outwards. The four polarised headers (CON4 to CON7) can then be installed with their plastic locking tabs oriented as shown. Again, make sure they sit flat against the PC board before soldering their pins.

Follow these parts with the 10µF and 100µF electrolytic capacitors, taking care to ensure they are correctly oriented. The two 0.1Ω resistors can now be installed. These resistors only dissipate about a quarter of a watt each, so they can be mounted flush against the surface of the board.

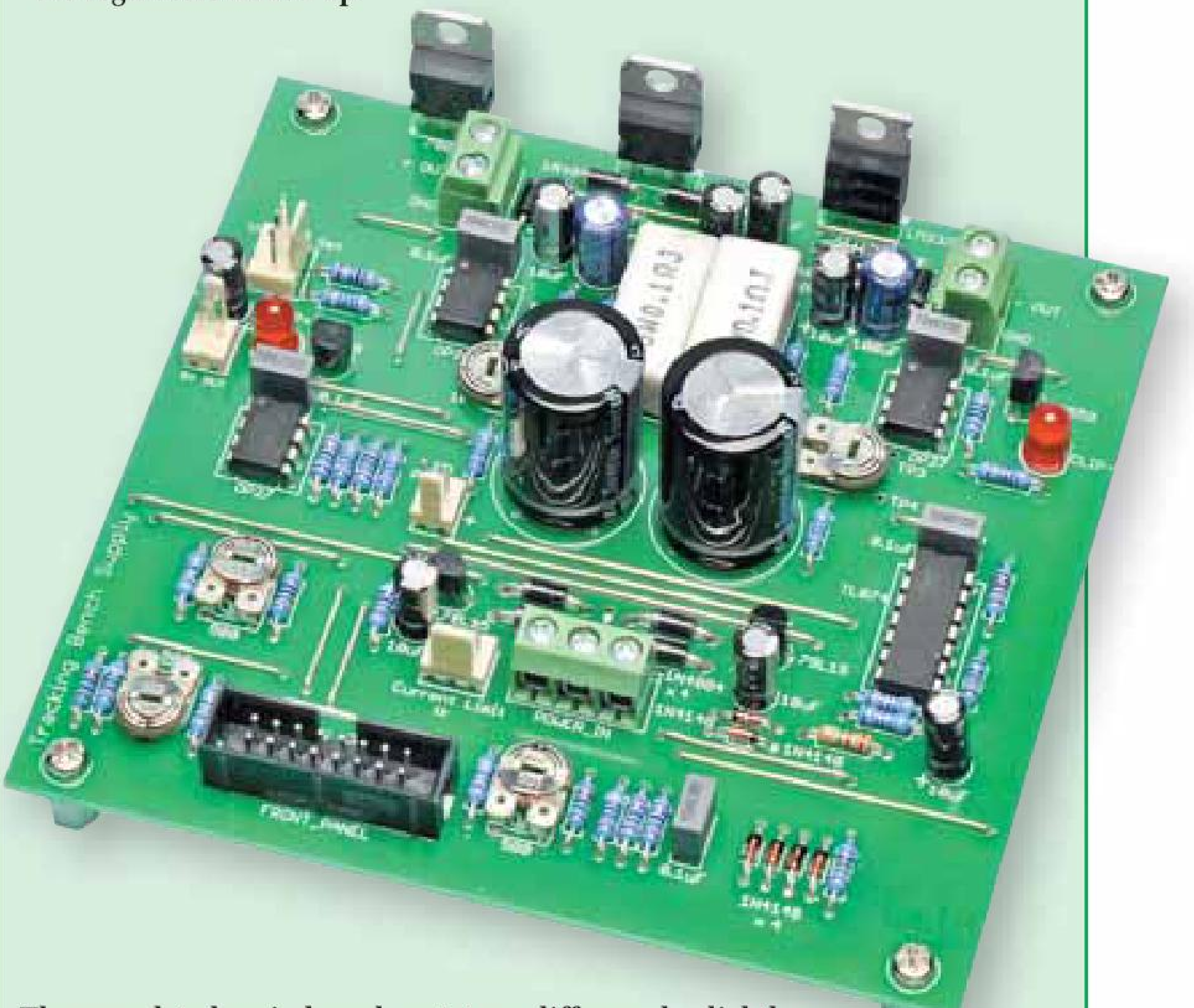
Mounting the regulators

Regulators REG1 (LM317T), REG2 (LM337T) and REG5 (7805T) can now be mounted along the top edge of the board – see Fig.8. Don't get them mixed up, and be sure to push them down all the way into the holes before soldering one pin of each regulator.


7805
LM317T
LM337T
CON2
CON3
V+ OUT
0V OUT
V– OUT
0V OUT
D5
D6
D7
D8
D9
D10
120Ω
10µF
100µF
100nF
TVS
CON6
(TO VR1)
10k
1k
LED1
LED2
BC549
BC559
IC1 LM833
IC2 LM833
IC3 TL074
IC4 LM833
VR3
VR4
VR5
VR6
VR7
500Ω
4.7k
68Ω
0.1Ω 5W
4700µF
CON5
CON4
3.3k
47k
22k
110k
11k
79L15
78L15
D1
D2
D3
D4
LK1
91k*
CON7
(TO VR2)
CON1
AC POWER IN
D11
D12
4148
4004
10M
Tracking Bench Supply
18105121
9.1k
820Ω
27k
3.0k
2.7k
D13
D14
D15
D16
CON8 (TO FRONT PANEL BOARD)

*USE 150kΩ RESISTOR & INSTALL LK1 FOR PLUGPACK-POWERED VERSION ONLY

Fig.8: follow this component layout diagram to build the main PC board. Make sure that all polarised parts are correctly oriented and be careful not to get the regulators mixed up.



The completed main board prototype differs only slightly from the final version shown in Fig.8. It's connected via a number of cables that terminate in headers and screw terminal blocks.

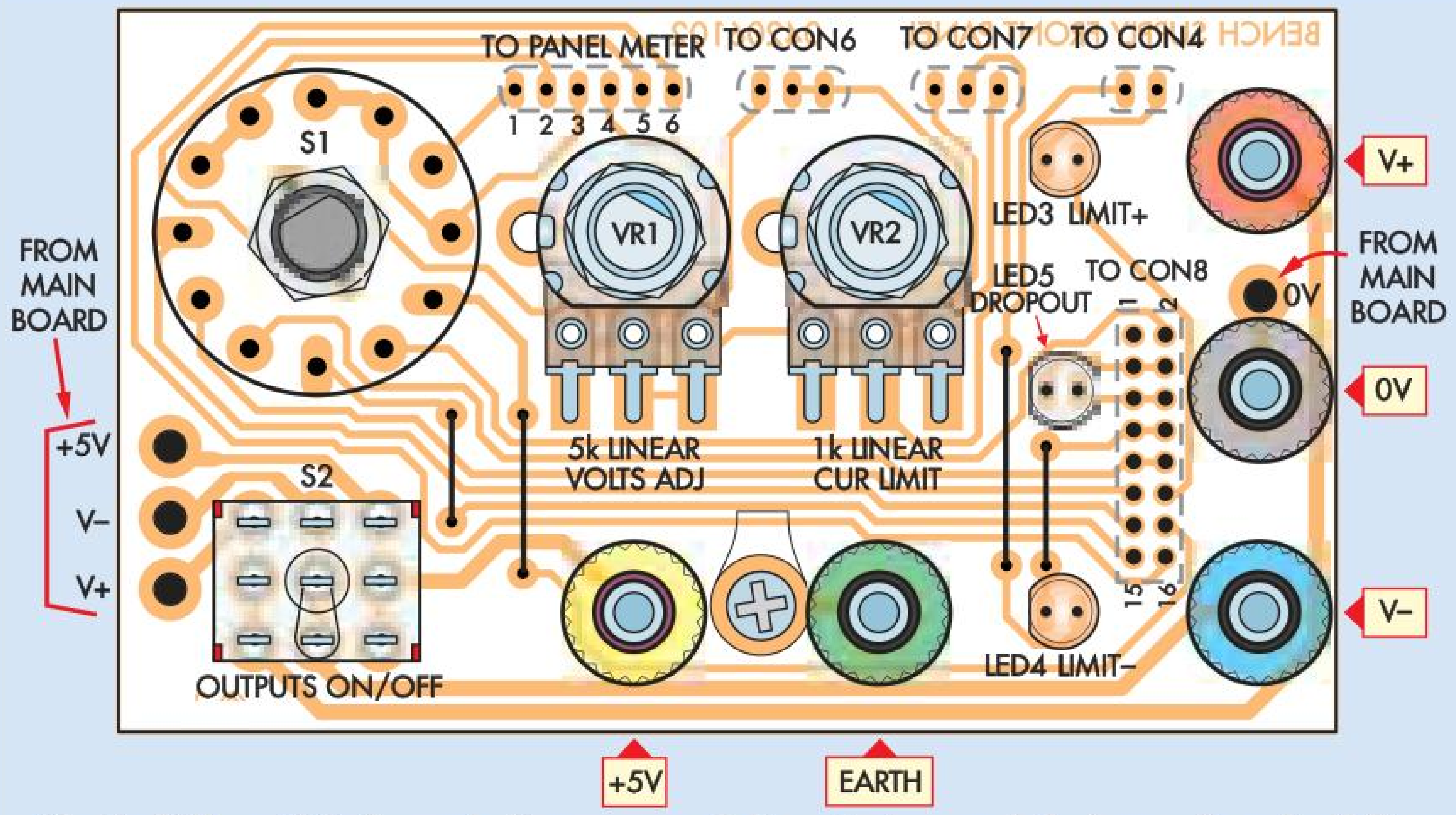
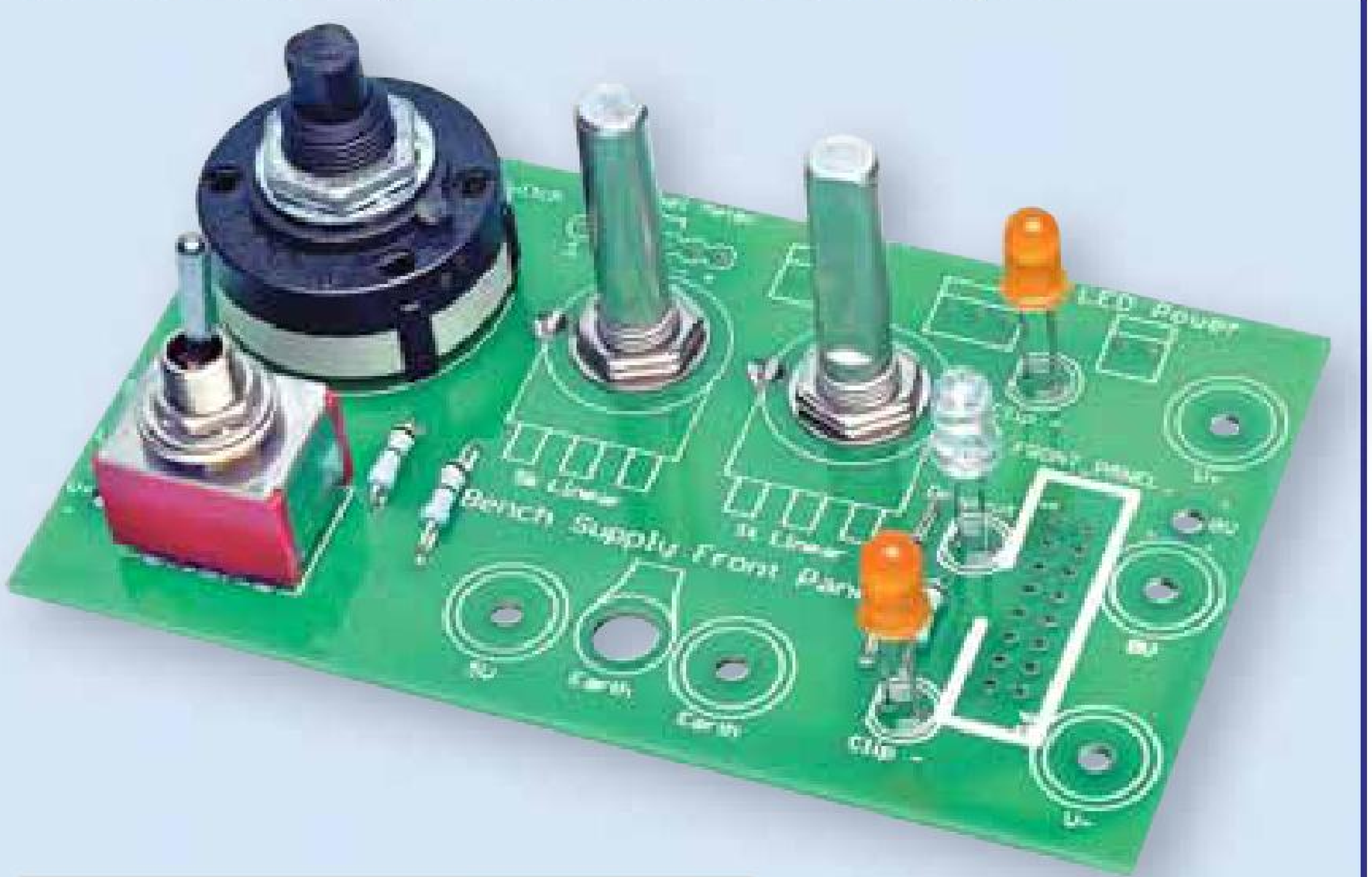


Fig.9: follow this layout diagram and the photograph below when building the front panel PC board. Note that the binding post terminals are soldered to the board after they have been mounted on the front panel.



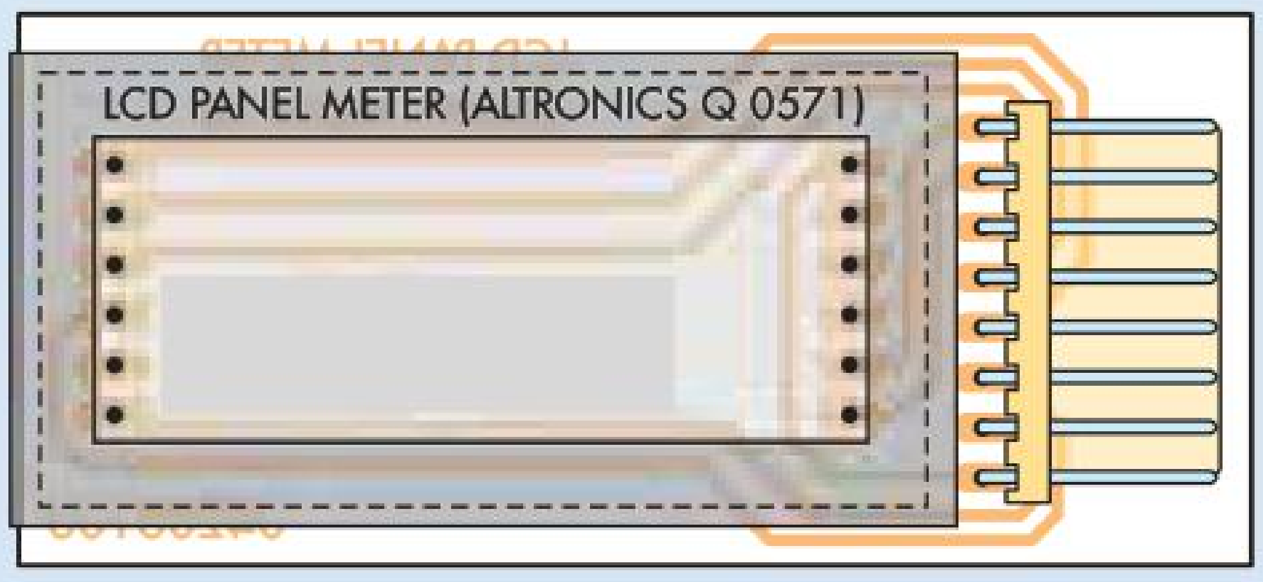


Fig.10: this assembly is only required if you are using the Altronics LCD panel meter. The LED panel meter already comes on its own PC board with a header.

That done, check that each metal tab is at a right angle to the PC board before soldering its remaining leads (if it isn't, re-melt the solder on the first lead and adjust it).

Once the regulators are in place, all that's left are the two large electrolytic capacitors. Once again, take care with their orientation.

Front panel board assembly

The smaller front panel board is coded 852 and the parts layout is shown in Fig.9. Begin by installing the four wire links. You can either use 0.71mm tinned copper wire or 0Ω resistors if preferred.

That done, use flat pliers to bend the pins of the two 16mm rotary potentiometers at right angles, so that they project out in the same direction as the shafts. Bend them as close to the potentiometer bodies as possible, then remove the nut and washer from each pot.

Next, take the 5kΩ potentiometer (VR1) and insert the shaft through the indicated hole on the PC board, with the body on the copper side. When it is correctly oriented, the metal tab will fit through the small adjacent hole.

The potentiometer's pins should just touch the three corresponding copper pads, but it's OK if they don't quite reach – solder can bridge the gap. Line the pins up with the pads and place the washer and nut over the shaft. Do the nut up finger-tight, then centre the pins in the pads and solder all three.

Once the pins have been soldered, tighten the nut down firmly. It is also a good idea to flood the pad around the small metal tab with solder. It probably won't adhere to the metal of the pot, but it will help prevent strain on the soldered pins when the shaft is rotated.

Repeat these steps for the 1kΩ potentiometer (VR2) which goes alongside.

Rotary meter switch

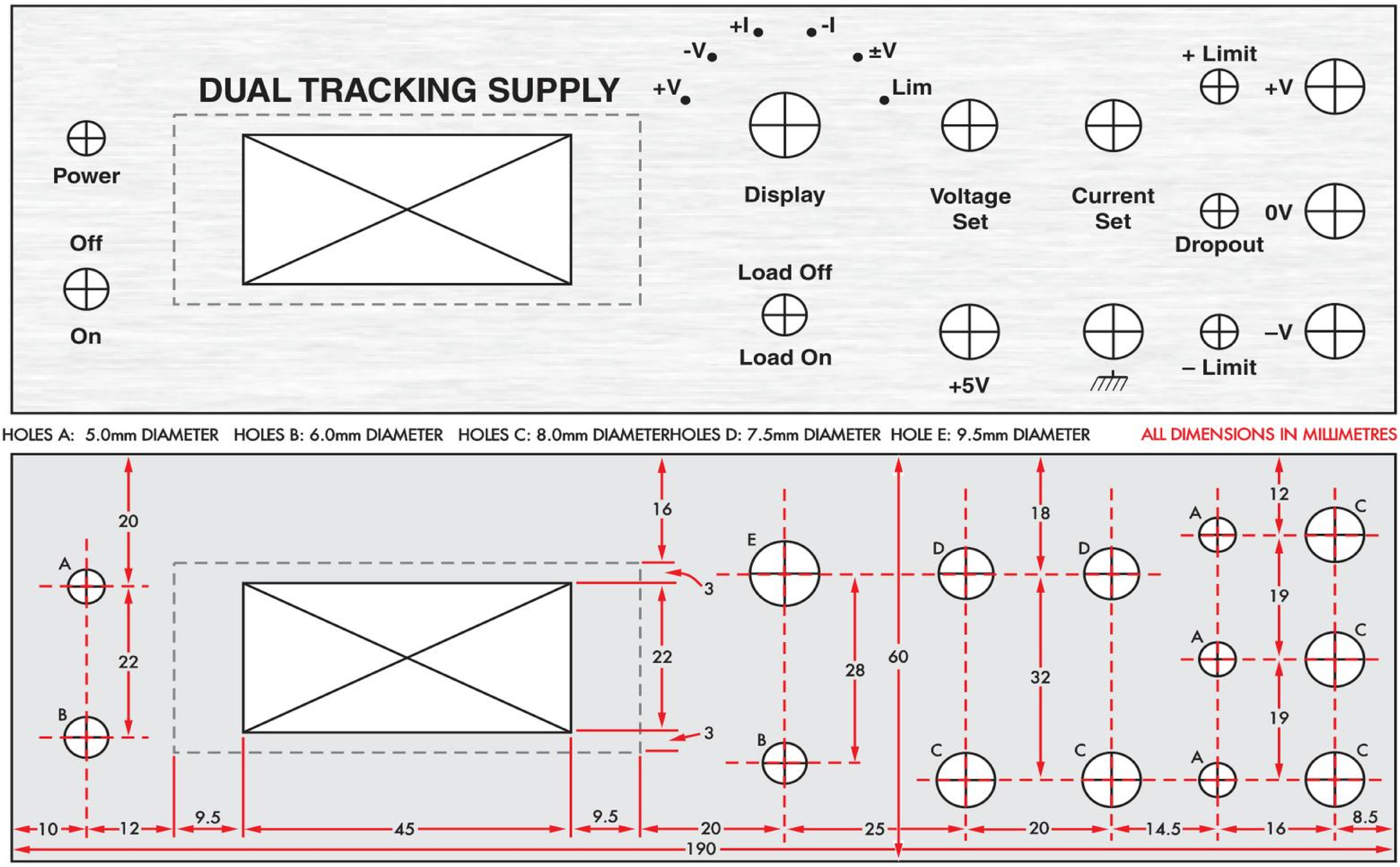
The next step is to install the 6-way, 2-pole rotary switch (S1). There are two different ways it can be oriented, but only one is correct. The mounting procedure is as follows:

1) Rotate the switch shaft all the way in one direction, then back two positions (ie, back two clicks).
2) Fit the switch to the board so that the flat part of its shaft faces towards the bottom of the board (ie, towards toggle switch S2 – see photo).
3) Solder one of the outer pins and check that the switch body is sitting flat against the board. Check it from all angles since it has four plastic 'feet' and they must all be touching the board surface. If this checks out, solder the diagonally opposite pin, then check the switch again before soldering the remaining pins.

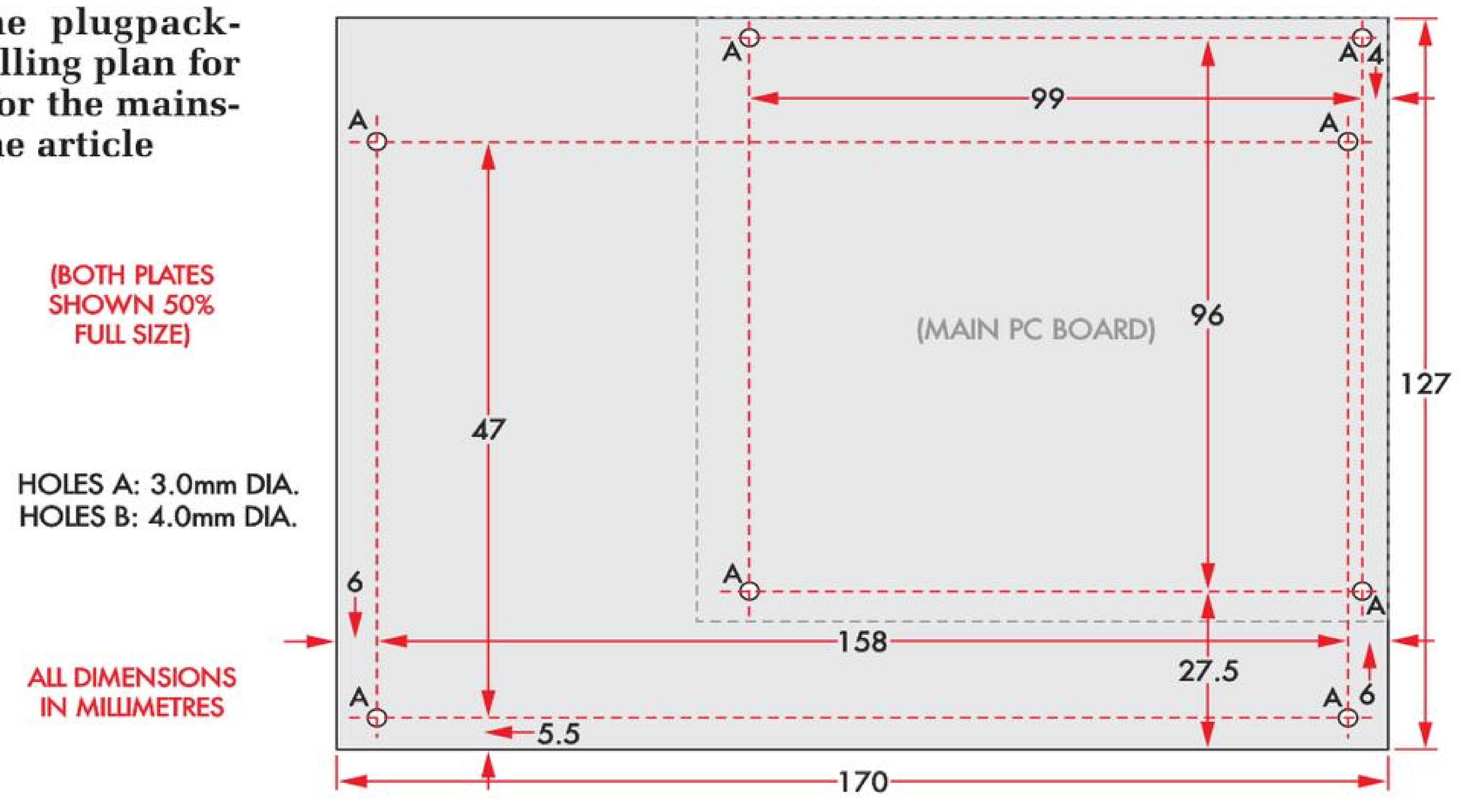
The rotary switch shaft needs to be shortened and now is a good time to do it. It only takes a few strokes with a hacksaw to cut through the soft plastic. Cut it so that its end lines up with the ends of the potentiometer shafts (ie, about 28mm above the board surface), then use a fine file to remove any swarf. This will leave a stub a little under 10mm long, which is just enough to attach the knob.

It's better to err on the side of cutting it slightly too long and file it down if necessary.

Next, install toggle switch S2. It must be orientated so that the switch actuator operates vertically. Press it down hard into the holes until it sits


DUAL TRACKING SUPPLY
+I
-I
-V
±V
+V
Lim
+ Limit
+V
Power
Display
Voltage Set
Current Set
0V
Dropout
Off
On
Load Off
Load On
+5V
–V
– Limit
HOLES A: 5.0mm DIAMETER HOLES B: 6.0mm DIAMETER HOLES C: 8.0mm DIAMETER HOLES D: 7.5mm DIAMETER HOLE E: 9.5mm DIAMETER
ALL DIMENSIONS IN MILLIMETRES
A
B
C
D
E
20
22
16
3
22
3
28
60
18
32
12
19
19
10
12
9.5
45
9.5
20
25
20
14.5
16
8.5
190

Above: front and rear templates for the plugpack-powered version. Opposite: a baseplate drilling plan for the plugpack-powered version. Templates for the mains-powered version are shown at the end of the article


(BOTH PLATES SHOWN 50% FULL SIZE)
HOLES A: 3.0mm DIA.
HOLES B: 4.0mm DIA.
ALL DIMENSIONS IN MILLIMETRES
(MAIN PC BOARD)
A
99
4
96
127
47
6
158
27.5
6
5.5
170

flat on the PC board, then secure all nine tabs by flooding each hole with solder.

LED3 to LED5 can now be installed. The middle one (LED5) is a red high-brightness type, while the other two are standard amber or orange LEDs. They must all be installed with their bodies 12mm above the PC board.

The easiest way to do this is to use a cardboard spacer. Cut a piece of cardboard 12mm wide and place it between the legs of the first LED to be installed. Insert this LED into the PC board, with the flat side orientated as shown, and push it down against the cardboard spacer. It's then just a matter of ensuring that the LED is perpendicular to the board before soldering its leads.

This procedure is then repeated for the other two LEDs.

LCD adaptor board assembly

This board (code 853) is optional, and is only necessary if you are using the LCD panel meter. Aside from the meter, the only other component mounted on it is an 8-way right-angle polarised header.

Fig.10 shows the assembly details. Begin by mounting the polarised header. Orient it as shown and make sure it is sitting flat against the board before soldering it in place.

The LCD can now be fitted. It goes in with the label that carries the model number (720000) towards the top. The adjustment trimmer on the rear of the LCD meter should also be closer to the top.

The alternative LED panel meter comes with a header already mounted on the rear (see Fig.11), so an adaptor board isn't necessary.

Attaching the ribbon cables

Unfortunately, headers cannot be fitted to the front-panel board because it is

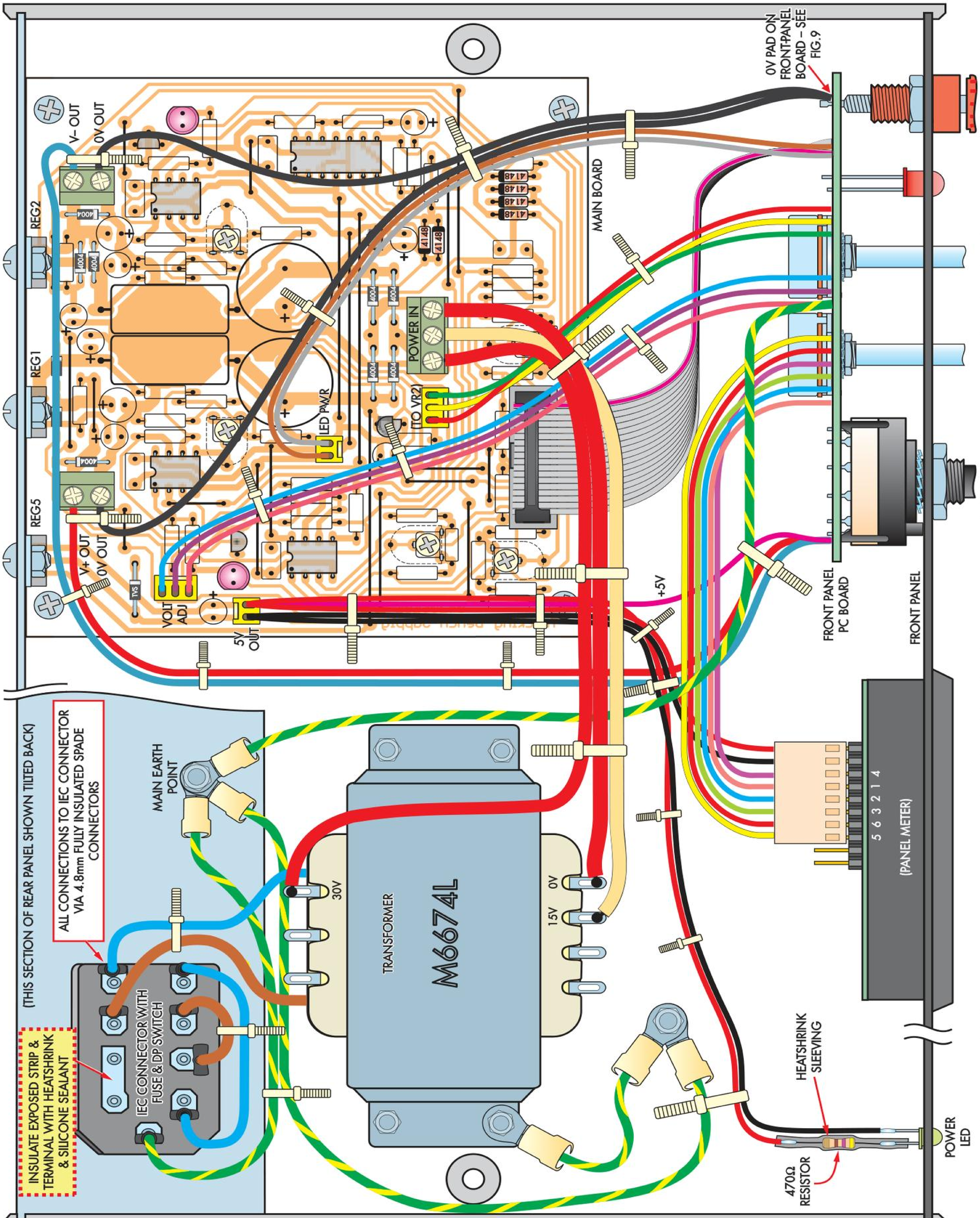

V– OUT
0V OUT
REG2
REG1
REG5
V+ OUT
0V OUT
VOLT ADJ
5V OUT
+5V
4148
4004
TVS
MAIN BOARD
POWER IN
LED PWR
(TO VR2)
0V PAD ON FRONT-PANEL BOARD – SEE FIG.9
FRONT PANEL PC BOARD
FRONT PANEL
5 6 3 2 1 4
(PANEL METER)
HEATSHRINK SLEEVING
470Ω RESISTOR
POWER LED
TRANSFORMER
M6674L
30V
0V
15V
MAIN EARTH POINT
ALL CONNECTIONS TO IEC CONNECTOR VIA 4.8mm FULLY INSULATED SPADE CONNECTORS
(THIS SECTION OF REAR PANEL SHOWN TILTED BACK)
IEC CONNECTOR WITH FUSE & DP SWITCH
INSULATE EXPOSED STRIP & TERMINAL WITH HEATSHRINK & SILICONE SEALANT

Fig.11: here's how to install the parts in the case and complete the wiring for the mains-powered version. Be sure to use fully-insulated spade connectors for all connections to the IEC socket, and fit cable ties to the low-voltage and signal leads, so that they cannot possibly contact the IEC connector if they come adrift.

too close to the front panel itself. As a result, all the wires to the front panel are soldered into place, the exception being the earth wire, which is attached via a crimped eyelet connector.

All the permanently soldered wires either have connectors which mate with headers on the main board and display panel, or they go to screw terminal blocks. This makes it quite easy to remove the main PC board if necessary.

First, it is necessary to cut ribbon cables of appropriate lengths. Here's the procedure:

1) Take a piece of 16-wire ribbon cable and cut it into three lengths: 200mm (A), 120mm (B) and 120mm (C).

2) Separate lengths A and B into smaller wire bundles (see Table 2). Do this by making a small nick between strands (with fine scissors) and then gently pulling the wires apart until you are left with two smaller ribbons. Cut these ribbons to the lengths shown in the table.

Table 2: Wiring cables

From	To	Purpose	Strands	Length	Cable set
Main board	Front panel	Voltage adjust	3	200mm	A
Main board	Front panel	Current adjust	3	160mm	A
Main board	Front panel	5V Power	1	105mm	B
Main board	Front panel	LED Power	2	140mm	A
Main board	Front panel	Misc. signals	16	120mm	C
Main board	Power LED	Power indicator	2	200mm	A
Main board	Panel meter	Meter power	2	160mm	A
Front panel	Panel meter	Meter signals	6	120mm	B

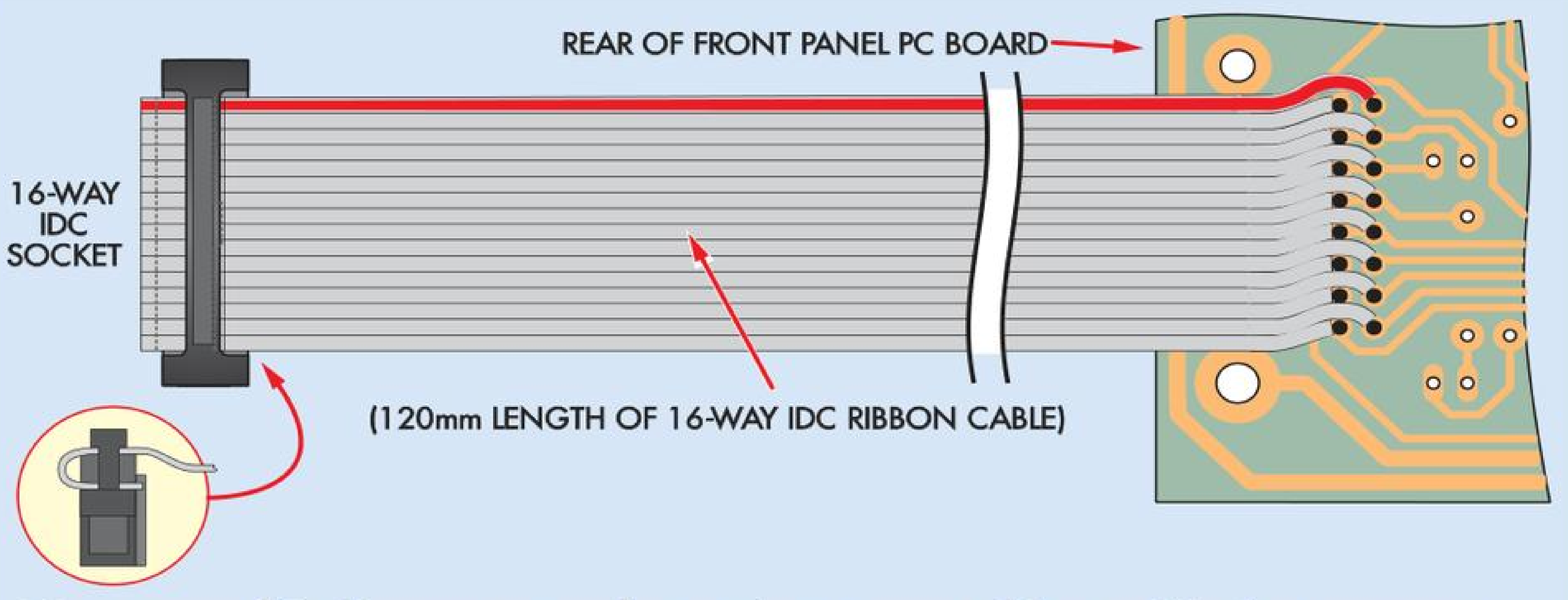

REAR OF FRONT PANEL PC BOARD
16-WAY IDC SOCKET
(120mm LENGTH OF 16-WAY IDC RIBBON CABLE)

Fig.12: use this diagram to make up the 16-way ribbon cable that connects between CON8 on the main board and the 2 × 8-way pad arrangement on the front-panel board.

3) Take the Voltage Adjust, Current Adjust and LED Power cables and separate the strands at each end by 10mm. Strip 5mm of insulation from each (an automatic stripping tool will make this much easier, as it will strip all the wires in the ribbon at once). Tin the exposed conductors.

4) Solder these three ribbon cables to the front panel board where indicated on the overlay (ie, at the 'TO CON6', 'TO CON7' and 'TO CON4' positions) . The cables enter from the non-copper side.

The order of the colours doesn't matter, but if you make them match the wiring diagram (Fig.11), it will be easier to follow.

5) Install a polarised header connector at the other end of each of these cables. It's just a matter of crimping and then soldering the header pins to the various leads before pushing them into the plastic header blocks (a soldering stand with alligator clips is handy for holding the pins as they are soldered).

Be sure to double-check that the connector orientation will be correct once the pins are inserted. The small metal tags on the pins line up with the rectangular slots in the sides of the blocks.

A small flat-bladed screwdriver (1mm wide) can be used to push the pins into the header blocks until they click into place. The same screwdriver can be pressed into the slots to remove the pins if they have been inserted in the wrong locations, but doing this is tricky, so it's best get them right first time.

6) Once those connectors are finished, separate and strip the 6-wire cable that goes to the LCD panel. Solder it to the front-panel PC board in the indicated location.

7) At the other end, pull the wires apart until each separate strand is 20mm long. Fit each wire with a header pin, then push them into the 8-way polarised connector block as shown in Fig.11 (make sure they click into place). Note that the order the strands are inserted into the block is not the same as their order within the ribbon.

8) There will be two free positions at the right-hand end of the header for the meter power leads. Separate and strip the ribbon (red and black wires), but only tin one end. Crimp and solder that end into two header pins, then insert them into the remaining positions for the 8-way header.

9) Strip 10mm of insulation from the other end of this cable. Do the same at one end of the Power Indicator ribbon and also for the single 5V Power strand.

10) Take the ground strand of the Meter Power ribbon and twist it together with the ground strand of the Power Indicator ribbon. Tin them both, then do the same for all three 5V power strands.

11) Crimp and solder both tinned junctions into header pins. Push them into the 2-way connector block, taking care to get them the right way around.

12) Separate, strip and tin the other ends of the Power Indicator ribbon and 5V Power strand.

13) Take cable C (120mm) and crimp it to the 16-way IDC connector using an IDC crimping tool or, at a pinch, a vice. Fig.12 shows the details. If you are using rainbow cable, then use the blue wire to indicate pin 1.

14) Separate the strands at the other end of the cable by 12mm and strip 5mm of insulation from the ends. An automatic wire stripper will do

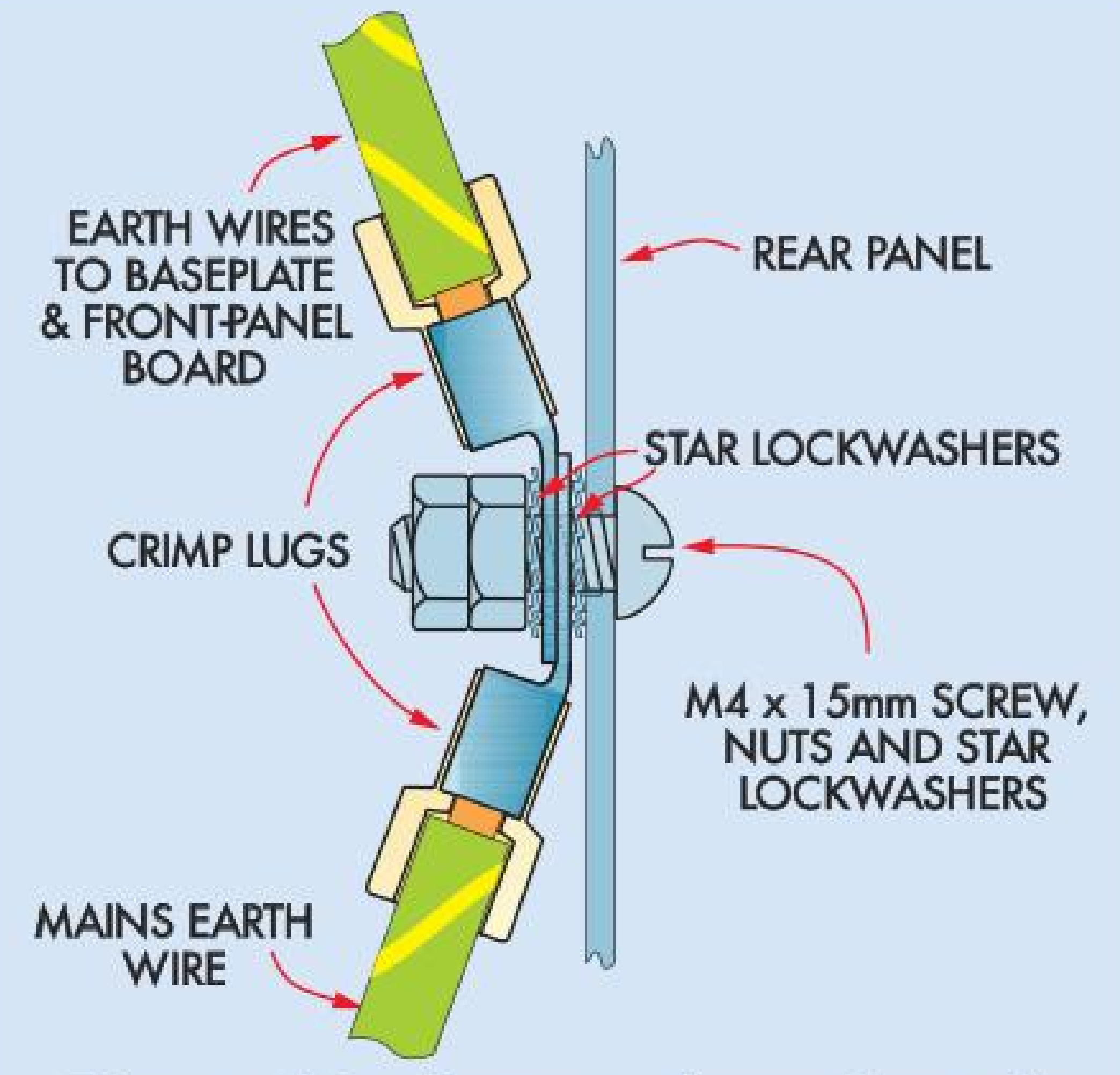

EARTH WIRES TO BASEPLATE & FRONT-PANEL BOARD
REAR PANEL
STAR LOCKWASHERS
CRIMP LUGS
M4 x 15mm SCREW, NUTS AND STAR LOCKWASHERS
MAINS EARTH WIRE

Fig.13: this diagram shows how the earth leads are secured to the rear panel. The second nut locks the first, so that the assembly cannot possibly come loose.

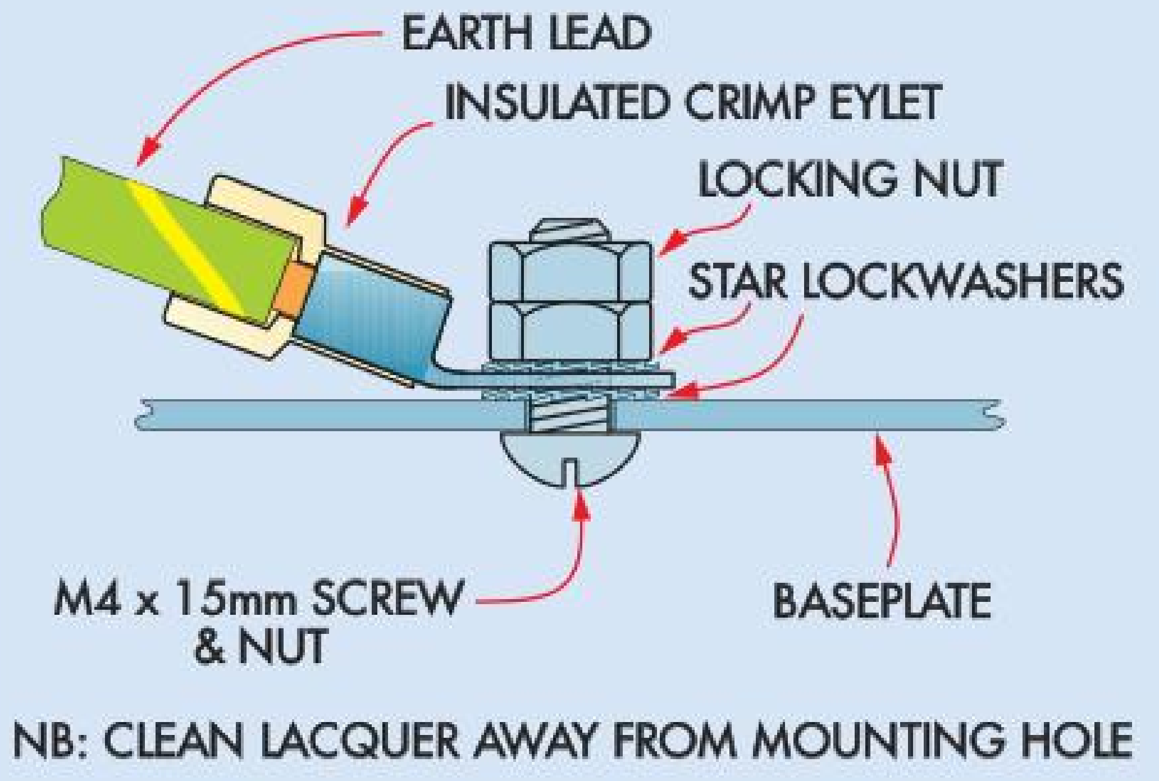


Fig.14: a similar scheme to that shown above is used to secure the earth leads to the baseplate.

Earthing the transformer safely

If you have lacquered the baseplate or if it is made from PC board material, you will need to separately earth the transformer frame. This means that the earth point on the baseplate will have two eyelet lugs attached to it rather than just one – see Fig.11.

First, cut an 80mm length of green/yellow mains-rated wire and crimp an eyelet lug on both ends. That done, scrape the passivation layer off the transformer's frame surrounding the mounting hole nearest the earth lug. A file with a broad, flat end will do this job quickly.

The earth lugs on the baseplate should be secured in the same manner as the rear-panel earth lugs – see Fig.14. This involves using a star washer on either side of the earth lugs and two nuts so that the assembly can't come loose.

about six at a time. Once you are finished, twist and tin the exposed strands of each wire.

15) Solder these wires to the DIL pads on the copper side of the front-panel board (ie, at the 'TO CON8' position) – see Fig.12. Pin 1 of CON8 on the main board goes to pin 1 of the DIL pads on the front-panel board (top-right as viewed from the copper side), pin 2 goes to pin 2 and so on.

The easiest way to do this is to first insert eight wires (every second one in the ribbon) into their holes down one side and solder one at either end. The other six wires on that side can then be soldered, after which, the eight wires on the other side can be inserted and soldered individually (you will need tweezers or needle-nose pliers to insert them into their holes).

Finishing the front panel

If you are building the supply from a kit, the plastic front panel will probably be supplied pre-drilled and cut. It is also possible that the baseplate and/or rear panel will already be cut to size and drilled. If this is the case, skip the sections explaining how to prepare these panels.

The drilling templates for the front and rear panels need to be photocopied, cutout and taped to the panels. The plugpack version is shown on page 37, and the mains-powered version at the end of this article. Note that both baseplates are shown half-size (50%). Most copier machines have reduction/enlarging facilities.

Leave the panel meter cutout for last. The larger rectangular cutout is for the LED panel meter, while the smaller cutout is for the optional LCD meter.

Either way, to make the cutout, drill a 3mm hole a few millimetres inside each corner, then a row of holes between each of these corner holes. Do not let any hole go outside the outline. That done, use a cutting tool to remove the plastic between each hole, then knock out the centre piece.

LED panel meter mounting

If you are using the LED panel meter, begin by removing the two screws at the rear to detach the bezel. Be careful not to scratch the red perspex window, which you can remove now (otherwise it will fall out).

Carefully file the edges of the panel meter cutout until it is a clean rectangle, which the bezel posts can fit through. Avoid making the hole too large and keep it horizontal – the tighter the fit, the better.

The front-panel artwork(s) can can be trimmed, laminated or covered with a protective film, and attached to the panel using double-sided tape. You can then cut the holes out using a sharp hobby knife.

Next, insert the bezel through the panel from the front and carefully place the red perspex inside it. Attach the display to the rear side using the two screws you removed earlier.

Because the front panel is relatively thin, the LED panel meter will be free to move backwards and forwards. To solve this, place the panel face-down so that the meter is pressed firmly against it, then flow a generous amount of hot-melt glue around the edges, filling the gap between the plastic panel and the meter. Don't disturb the panel until it has cooled to room temperature.

This isn't a permanent attachment – you can remove the glue if you pull hard enough with a pair of pliers – but if you use enough glue it won't come loose of its own accord.

LCD panel meter mounting

Alternatively, to mount the LCD panel meter, first remove the two plastic clips on either side of the display. This is done by pulling each clip backwards until it rotates, un-hooks and detaches.

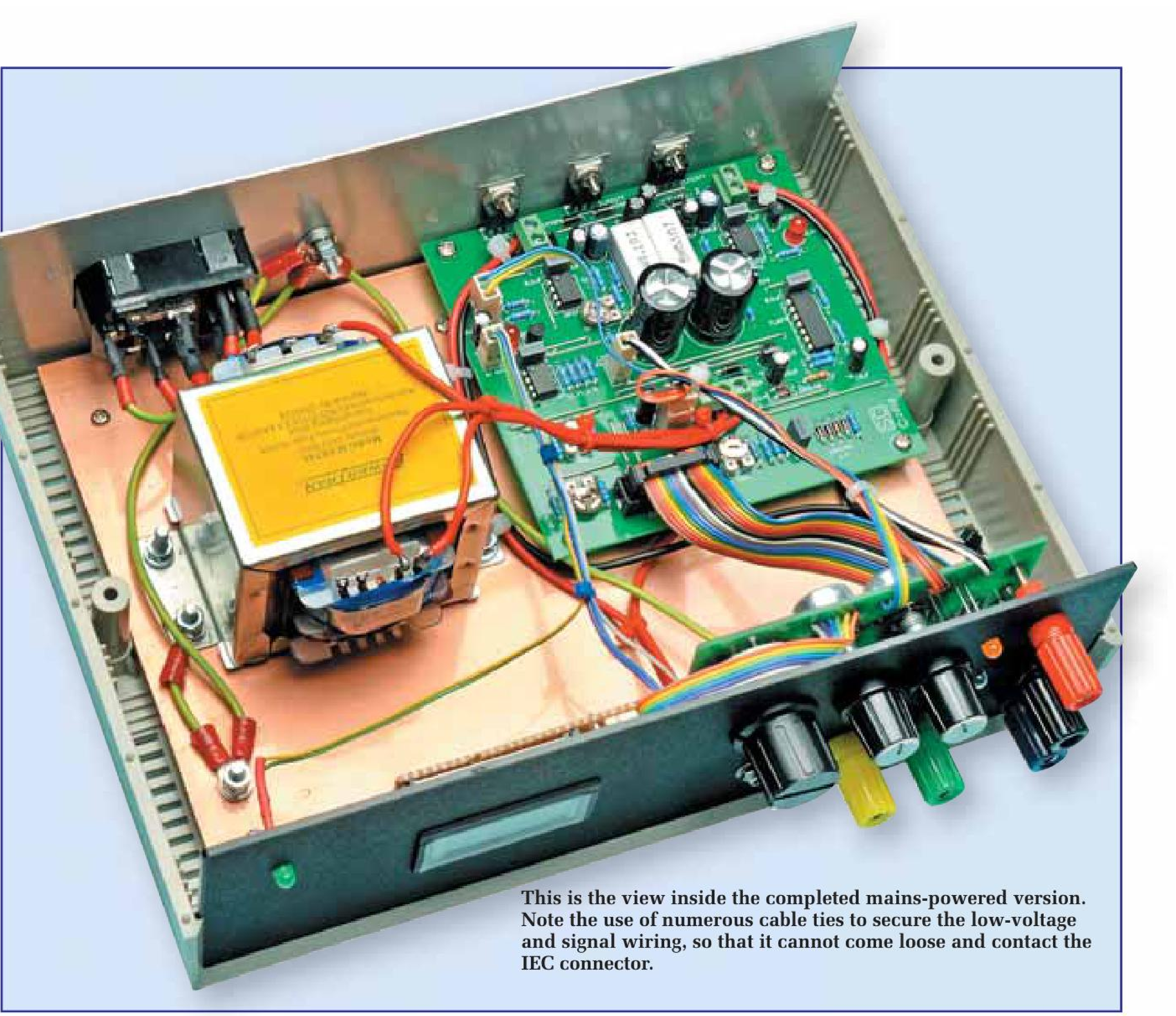
Now, carefully file the edges of the panel meter cutout until it is a clean rectangle, which the rear portion of the panel can fit through. Avoid making the hole too large and be sure to keep it horizontal – the tighter the fit, the better.

Next, attach the front panel artwork as described in the previous section, then insert the panel meter through the panel from the front. That done, re-attach each side clip by latching one side on and rotating the other side into place – the opposite of the procedure used to remove it. It should click into place. You can then press it forward until it's holding the display to the panel.

If the fit isn't quite perfect and the display can still move, use some hot-melt glue along the sides at the rear to secure it in place.

Completing the front panel

The next step is to mount the five binding posts on the front panel. Fig.9 and the photos indicate which colour goes where. Loosely attach them in place,



This is the view inside the completed mains-powered version. Note the use of numerous cable ties to secure the low-voltage and signal wiring, so that it cannot come loose and contact the IEC connector.

then undo the nuts on the rotary and load switches (S1 and S2) on the front-panel board and remove the washers. The piece of metal under the washer on the rotary switch (used for indexing) should be left in place.

The front-panel board can now be fitted to the front panel by inserting the switches and LEDs through their corresponding holes. At the same time, the binding post terminals should fit through their corresponding holes on the board. Push the board towards the front panel until the rotary switch and load switch are flush against it. The binding post terminals should all protrude through the rear of the PC board by an equal amount.

Once it is in place, refit the nuts and washers to the switches and tighten the nuts down firmly to secure the board in place. Check that everything is nice and straight and make sure that the front panel fits properly into the slot in the case.

The LEDs should project evenly through the front panel. If they don't, you will have to remove it and adjust their height.

Temporarily unscrew the end caps of each binding post so that you can see the wire insertion holes. Rotate each binding post so that its hole is easily accessible. They should be horizontal for the V+, 0V and V– posts, and vertical for the +5V and earth posts.

Once each post has been oriented correctly, solder it to its PC board pad and use pliers to fully tighten the nuts.

Install the three knobs now. The larger knob is for the rotary switch and is secured using a grub screw. The other two knobs push on to the pot shafts, but first make sure that the pointers are facing the right direction relative to the D-shaped hole at the rear. If the pointers don't face directly away from the flat portion, use a sharp knife or very thin screwdriver to prise the pointer face off, then insert it with the correct orientation.

All that remains to complete the front-panel assembly is to install the green power LED. Push it through its hole and use a generous blob of hot-melt glue at the back to prevent it from falling out. When the glue has cooled, trim its leads to about 10mm, leaving the anode lead slightly longer, then trim the 470Ω resistor leads and solder one end to the anode – see Fig.11.

DUAL TRACKING SUPPLY
Power
18.00
Display
Load Off
Load On
Voltage Set
Current Set
Dropout
+Limit
+5V

Our mains-powered prototype used the Altronics 3.5-digit LCD panel meter. Alternatively, the specified Jaycar LED panel meter can be used if you prefer a really bright readout.

Making the baseplate

The baseplate is made from an aluminium sheet or copper-clad PC board material. Cut the sheet to 248mm × 76mm using a guillotine or hacksaw, then drill holes as per the drilling diagrams.

It's a good idea to spray the baseplate with clear lacquer so that it won't oxidise (even if it's made from aluminium). If you do this, be sure to scrape away the lacquer surrounding the earth lug hole, so that the earth lug makes good electrical contact with the baseplate. You will also need to separately earth the transformer if you lacquer the baseplate – see transformer earthing panel.

Check that the baseplate's mounting holes line up with the plastic posts in the case. Since the cases can vary slightly in the post spacing, you may need to slightly enlarge some holes. Once it is correct, remove the 9mm tapped nylon spacers from the main PC board and attach them to the top side of the baseplate instead, using the drilling template as a guide to their locations.

The baseplate can now be secured inside the case using six No.4 self-tapping screws. Once it's in, slide the rear panel into the case and rest the main PC board on top of its spacers. Check that, with the regulators right up against the rear panel, the PC board lines up with its spacers. If not, you will have to enlarge the baseplate mounting holes in the appropriate direction.

Note that it may also be necessary to slightly bend the regulator legs so that they sit parallel with the rear panel.

Rear panel assembly

The aluminium rear panel holds the IEC power input connector and doubles as a heatsink for the main regulators. If it's not supplied with the case, you will have to cut a sheet of aluminium to 224mm × 155mm and drill it as shown in the drilling template.

Although the regulator mounting holes are marked on the drilling template, your regulators may be offset slightly, depending on how they've been soldered to the main board. For this reason, the best approach is to temporarily mount the main PC board in the case and slot the panel into place. The regulator metal tab holes can then be marked directly on the panel, rather than relying on the template.

The IEC socket outline can be marked using a scribing tool or sharp knife. Once that's done, drill a 6-7mm hole inside the outline and use a nibbling tool to complete the cut-out. The socket must ultimately be a tight fit, so do this carefully, leaving a small margin inside the marked outline. A small file is then be used to finish it off.

Again, it is a good idea to apply clear lacquer to the finished panel, but if you do so, you must scrape it off around the earth lug mounting hole on both sides. Once the panel is ready, press the IEC socket through and it should snap into place. After that, slide the rear panel into the case and check that everything lines up.

Assuming it's OK, remove the base plate from the case and attach the transformer to it using four M4 x 15mm machine screws, spring washers and nuts. Make sure the primary wires are towards the rear of the baseplate.

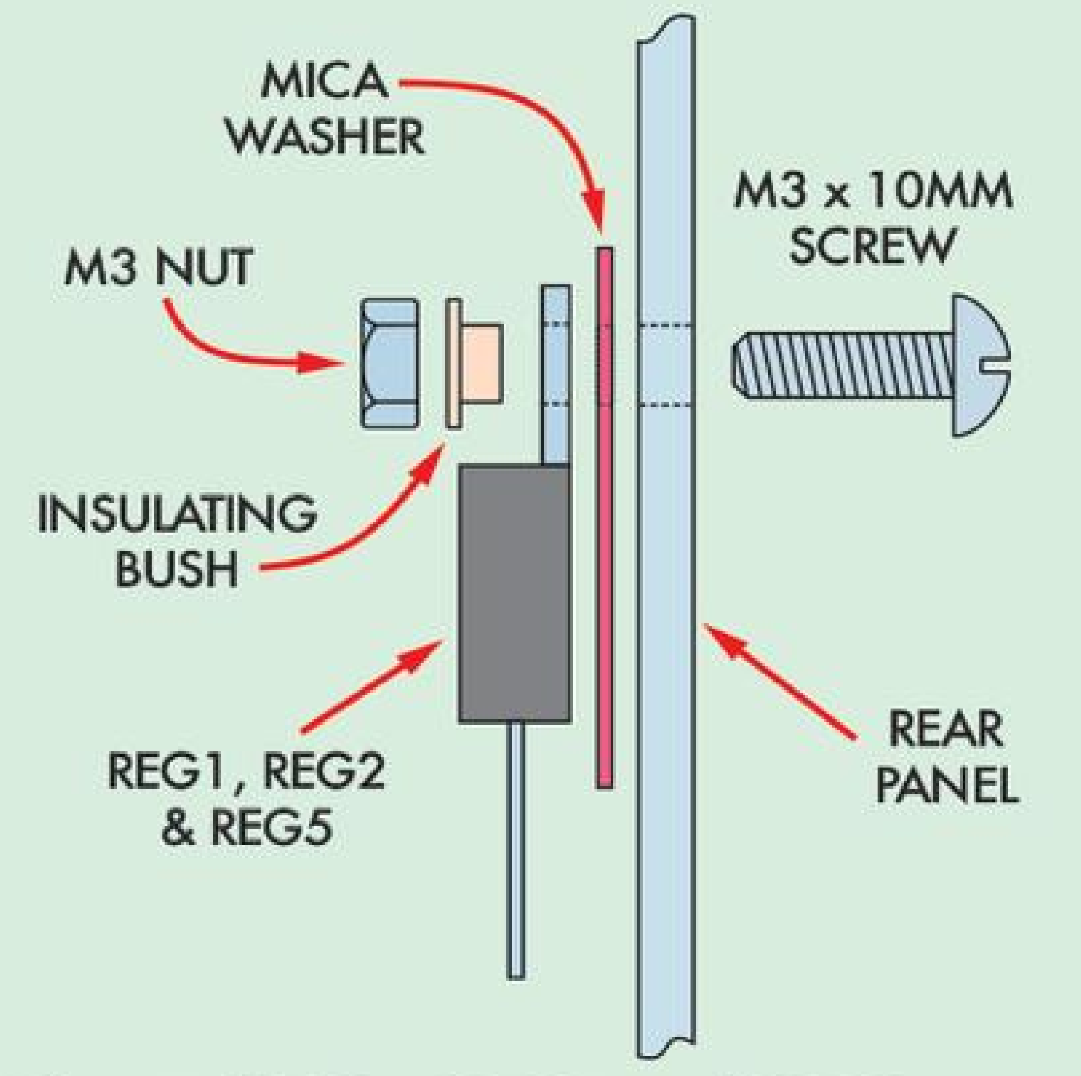


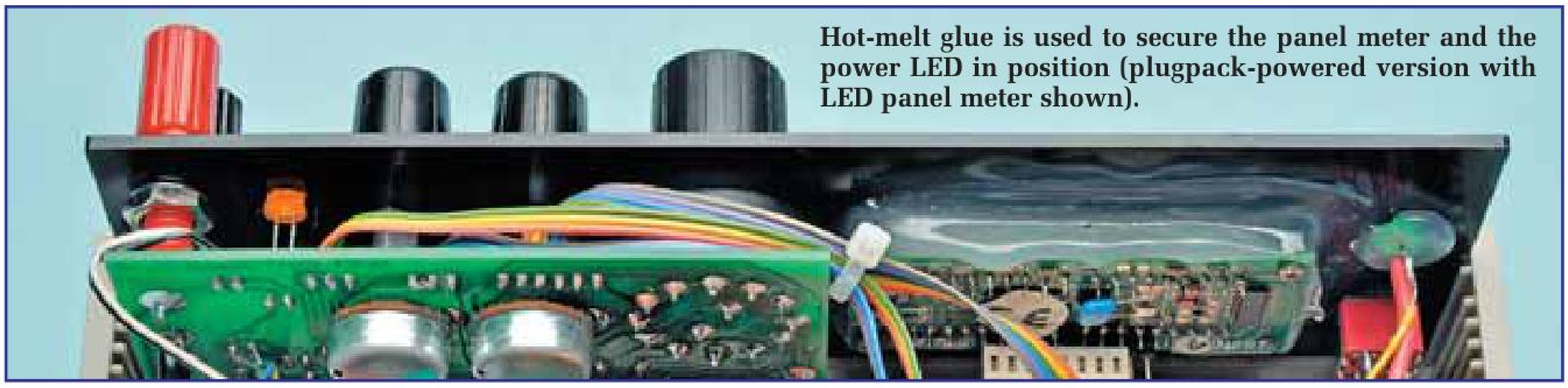
Fig.15: REG1, REG2 and REG5 must be insulated from the rear panel using a mica washer and insulating bush, as shown here.

Earth cables

It's now necessary to make up the following cables using green/yellow mains-rated wire:

1) Eyelet lug to 4.8mm fully-insulated spade lug, 90mm (IEC socket to rear panel earth point)
2) Eyelet lug to eyelet lug, 170mm (rear panel earth point to base plate earth point)
3) Eyelet lug to eyelet lug, 200mm (rear panel earth point to front panel binding post).

Only a ratcheting crimping tool can make safe and secure connections, so be sure to use one. Don't use a non-ratchet type as supplied with cheap automotive crimping sets – the earth connections are vital to ensure safety and a non-ratchet crimper cannot be relied on.



Hot-melt glue is used to secure the panel meter and the power LED in position (plugpack-powered version with LED panel meter shown).

Note that you should also insulate the exposed metal strip and terminal on the IEC socket using heatshrink and silicone sealant – see Fig.11.

These three earth cables are now attached to the rear panel. To do this, first insert an M4 × 15mm machine screw through the earth point on the rear panel and place an M4 star washer over the thread. Follow this with the eyelet lugs from all three cables, then place another star washer on top and install the nut.

Tighten this nut down very firmly, then fit a second nut in place. This will securely lock the first nut into position so that the assembly cannot possibly come loose – see Fig.13.

It's now just a matter of running the earth leads to their destinations, as shown on the wiring diagram (Fig.11). The cable with the spade lug goes to the earth lug of the IEC socket and must be pushed all the way on. The second cable goes to the earth point on the baseplate and is secured as shown in Fig.14. The third cable is fastened to the front-panel board, adjacent to the earth post.

The latter is connected using an M4 × 10mm machine screw, earth lug, star washer and nut. The nut goes between the PC board and the panel itself, so use pliers to hold it in place while you tighten the screw.

As mentioned earlier, if there is lacquer on either panel around the earth points, it must be scraped off (on *both* sides) before the earth screws are installed.

The baseplate (without the main PC board) can now be reinstalled in the case, ready for the next step.

Attaching the regulators

Regulators REG1, REG2 and REG5 can now be attached to the rear panel. They rely on the rear panel for heatsinking, but must each be electrically isolated from it using TO-220 insulation kits (ie, mica washers and insulating bushes). Fig.15 shows the details.

Begin by inserting M3 × 10mm machine screws through the three regulator mounting holes in the rear panel. That done, smear the three TO-220 mica washers with thermal transfer compound on both sides, then slide them over the screw shafts. The main board can now be slipped into position with the three screws passing through the regulator tabs (you will need to hold the screws heads in place while you do this).

Next, fit a plastic insulating bush to each regulator, then fit an M3 nut over the end of each screw and do it up finger tight. The main board can then be fastened to the baseplate using four M3 × 6mm machine screws, after which the three regulator screws can be tightened (hold the nuts with pliers so that they can't rotate).

Finishing the wiring

All that is left is to finish the chassis wiring, as shown in Fig.11. This mainly involves the wiring to the IEC socket and the transformer secondary connections.

First, make up the short cable sections which join the incoming live and neutral terminals to the switch terminals on the IEC socket. These ***must*** all be mains-rated wires, correctly colour coded and fitted with 4.8mm fully-insulated spade lugs at each end. Heatshrink can be used to improve the insulation if necessary.

As before, you must use a ratcheting crimping tool to attach these fully-insulated spade connectors. Once complete, push them on hard so that they can't come loose.

Next, trim the transformer's primary leads so that they are long enough to reach the two top switch terminals, adding a little extra so that they can flex slightly. Strip the ends, scrape away the enamel, attach 4.8mm fully-insulated spade connectors and fit them to the IEC connector as shown.

The remaining leads that connect to the front panel are soldered to pads from the copper side. To do this, place the front-panel face down and fill each remaining hole with solder. Twist the exposed conductors of the wires tightly together and tin them. It's then just a matter of re-melting the solder while pushing the tinned wire through the hole in the centre of each pad.

Once the wiring is completed, slot the front panel into the case and plug the various attached headers onto the main board – see Fig.11.

Don't forget the wires that run to screw terminal blocks CON1 to CON3 on the main board. Use heavy-duty hookup wire for the transformer connections to CON1, and for the connections to CON2 and CON3. The wiring to the power LED is run using ribbon cable, as described previously.

Cable ties

As shown in Fig.11, numerous cable ties are used to secure the wiring in place. **These are necessary to ensure that if a lead does come adrift, it cannot possibly reach the back of the IEC socket and thus come into contact with the mains voltage.**

In particular, keep the lead to the 30V terminal on the transformer short and secure it as shown in Fig.11. The leads to the front panel power LED must also be bound to other cabling so that the LED's leads cannot possibly contact the IEC socket if it comes adrift (the wiring diagram is not to scale).

Similarly, the leads to CON2 and CON3 must be secured right at the terminal blocks.

You are now ready to test your new power supply.

Testing the supply

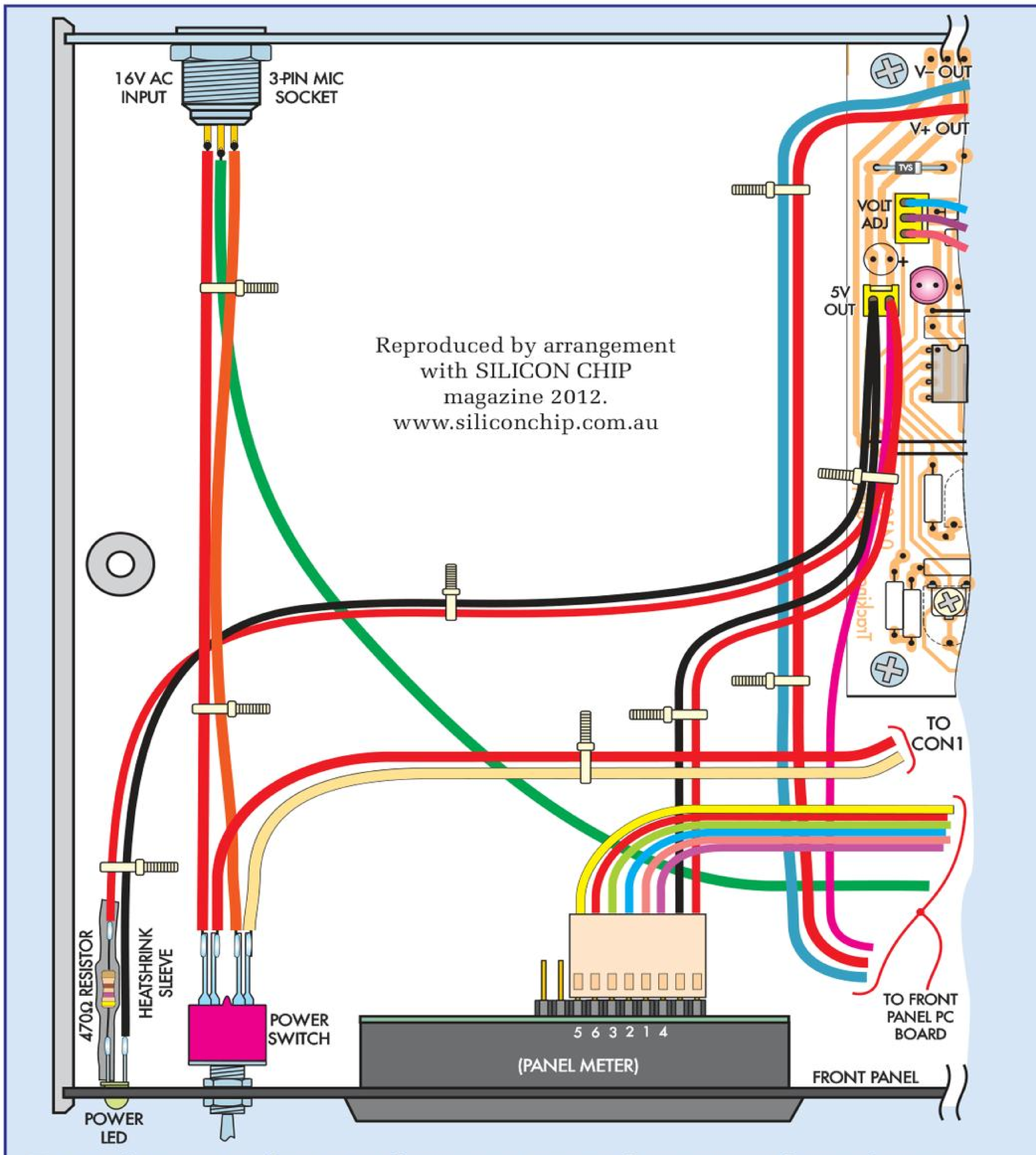
If you have built the mains-powered version, install the 500mA fuse in the IEC connector now. The fuseholder can also store a spare fuse, so if you have one, it's a good idea to fit this as well.

The step-by-step test procedure is as follows:

1) Plug a mains cord into the IEC connector and use your multimeter to check the earth connections (ie, check for continuity between the earth pin of the plug, the rear panel and the baseplate).
2) Set the voltage and current knobs mid-way and set the rotary switch fully anti-clockwise.
3) Switch both the load and power switches off (ie, up), then plug the unit into a 230V AC wall socket.
4) Switch on and check that the power LED lights. The other three front panel LEDs may light briefly, but should then stay off. The display should show a value in the range of 7V to 13V. If any of these conditions are not met after a couple of seconds, switch off immediately.

   If the power LED doesn't light, check the fuse and the power LED wiring. If they look OK, it could be a problem with the main board. Conversely, if the power LED lights but the display is not working, check the display wiring. If the display works but an incorrect value is shown, it could be a wiring or main board problem.

   If one (or both) of the limit LEDs is stuck on, there could be a problem with the current-limit potentiometer wiring or the main board. If the dropout LED lights, the main board probably has a fault.
5) If all is well, turn the voltage knob up and down and check that the voltage reading changes in response.
6) Turn the rotary switch one click to the right and check that the negative rail can also be correctly adjusted over the same range.
7) Turn the load switch on and off and check that it has no effect on the output voltage.



Reproduced by arrangement with SILICON CHIP magazine 2012. www.siliconchip.com.au

Fig.16: this version eliminates the mains wiring and power transformer by using an external 16V AC plugpack supply. It's wired as shown here.

Building the plugpack-powered version

IF YOU are building the plugpack-powered version, the PC boards can be installed into the smaller case as specified in the parts list last month. Alternatively, you can use the same case that's used for the mains-powered version.

The drilling template (baseplate and front panel) can be photocopied – see page 37. The rear panel is 190mm × 60mm and the baseplate is 170mm × 127mm. Note also that Altronics sell an anodised panel (H0468) to suit this case.

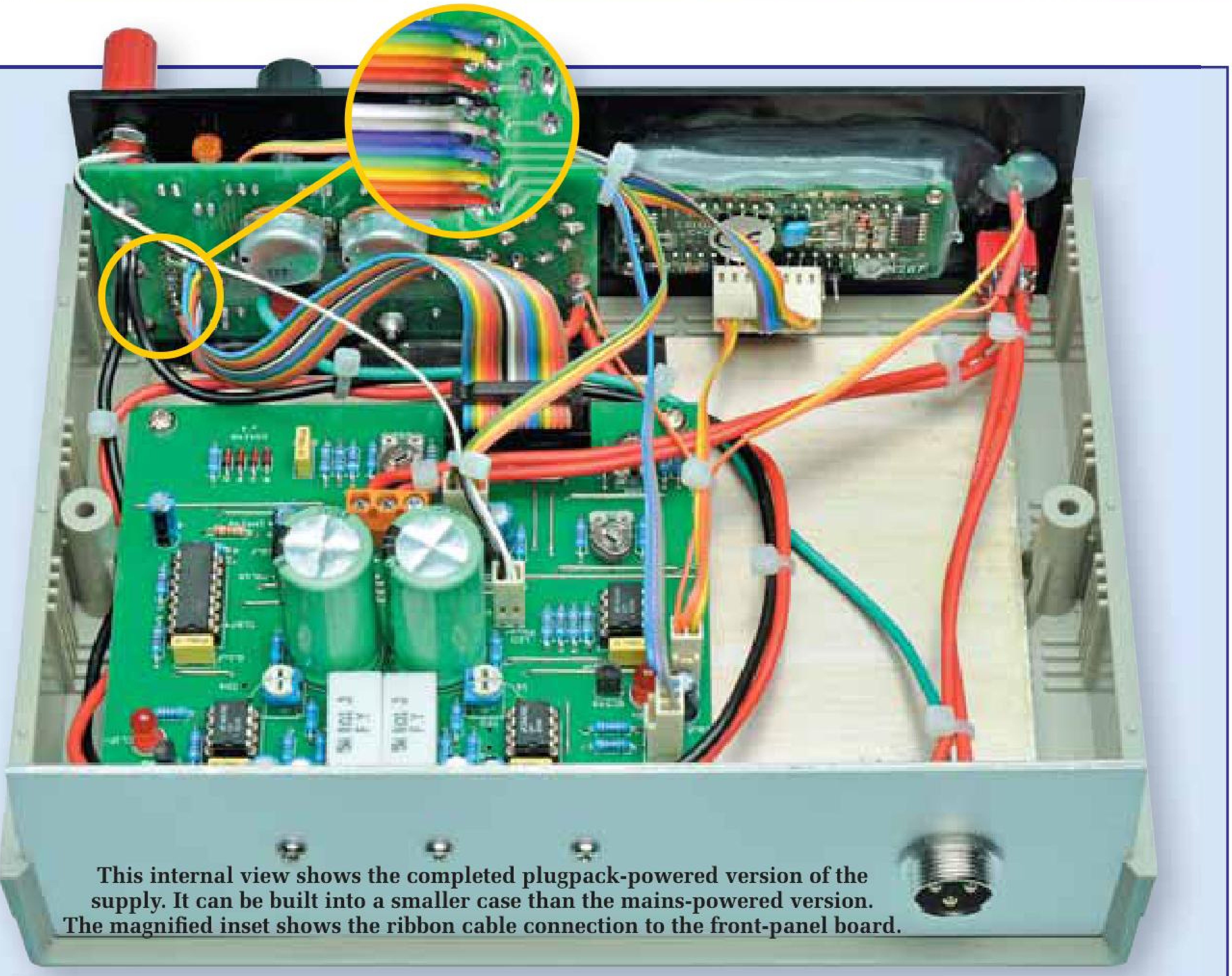
Trimming the supply

Five adjustments are necessary for maximum accuracy of the readouts and current-limit settings. These are best made when the supply is warm, so fit the lid and leave the supply switched on with no load for about 30 minutes (it can be trimmed cold, but then readings will be less accurate once it has warmed up).

When you are ready, remove the lid and get a plastic adjustment tool or a flat-bladed screwdriver with an insulated handle. The adjustments can then be made as follows:

1) Set the rotary switch to I+ and adjust VR3 to get a reading as close to zero as possible. Turning VR3 clockwise should increase the reading and you need to make a series of very small adjustments to find the minimum.

   If it won't go near zero no matter what you do, there could be a problem with IC1 or its adjacent components.
2) Turn the switch clockwise to I– and adjust VR4 to trim IC2 in the same manner.
3) Connect a DMM between the V+ (red) and 0V (black) binding posts and check that the load switch is on. Turn



This internal view shows the completed plugpack-powered version of the supply. It can be built into a smaller case than the mains-powered version. The magnified inset shows the ribbon cable connection to the front-panel board.

We have not provided a rear-panel drilling template as you simply mark and drill holes for the three regulator tabs, plus a 16mm hole at the other end to take a 3-pin microphone socket. This socket accepts a matching connector from the external plugpack supply.

For the larger case, you can use the same drilling templates as for the mains-powered version with just a few changes:

1) Do not drill the transformer mounting holes or the earth lug hole in the baseplate.
2) Instead of making the IEC socket cutout on the rear panel, drill a 16mm hole for the microphone socket.
3) Drill the power LED hole in the front panel 15mm higher than indicated.
4) Drill a 6.5mm hole 30mm below the power LED for the power switch

In either case, install the microphone socket and follow Fig.16 to wire up the power supply.

Once this wiring is complete, all that remains is to solder the 3-pin microphone plug to the plugpack lead. To do this, first shorten the bare wires from the plugpack so that they project 15mm from the sheath. Strip 5mm from each end and tin them.

Next, remove the screw holding the microphone plug together, along with the two screws that hold the metal clamp at the rear of the plug. The lead can then be fed through the rear of the plug and the wires soldered to the appropriate tabs on the connector. Make sure that the earth (green/yellow) wire goes to the pin nearest the U-shaped depression running along the plug body. The other two wires can go to either tab, since it is an AC plugpack.

Finally, reassemble the plug and the job is done.

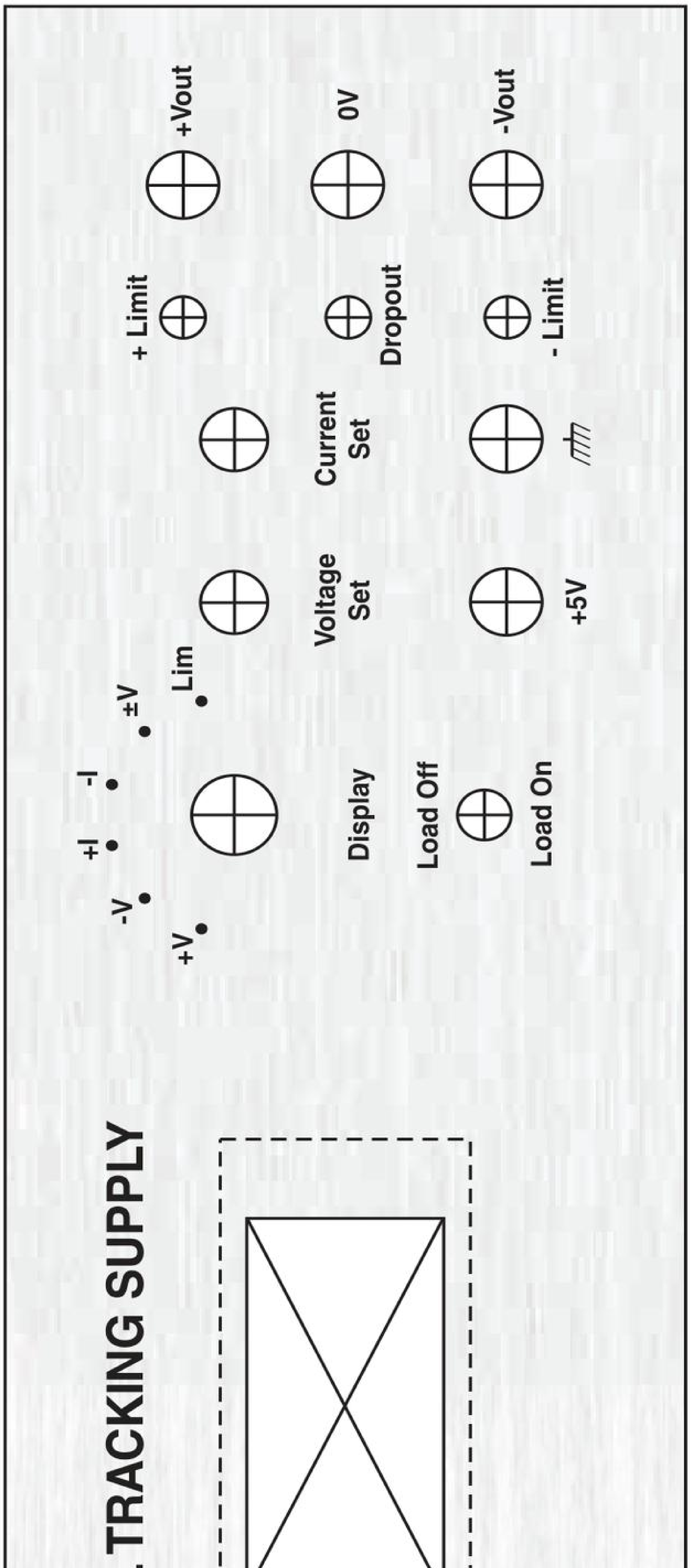
the rotary switch anti-clockwise to V– and adjust VR5 until the reading on the display is as close to the reading on your multimeter as possible.

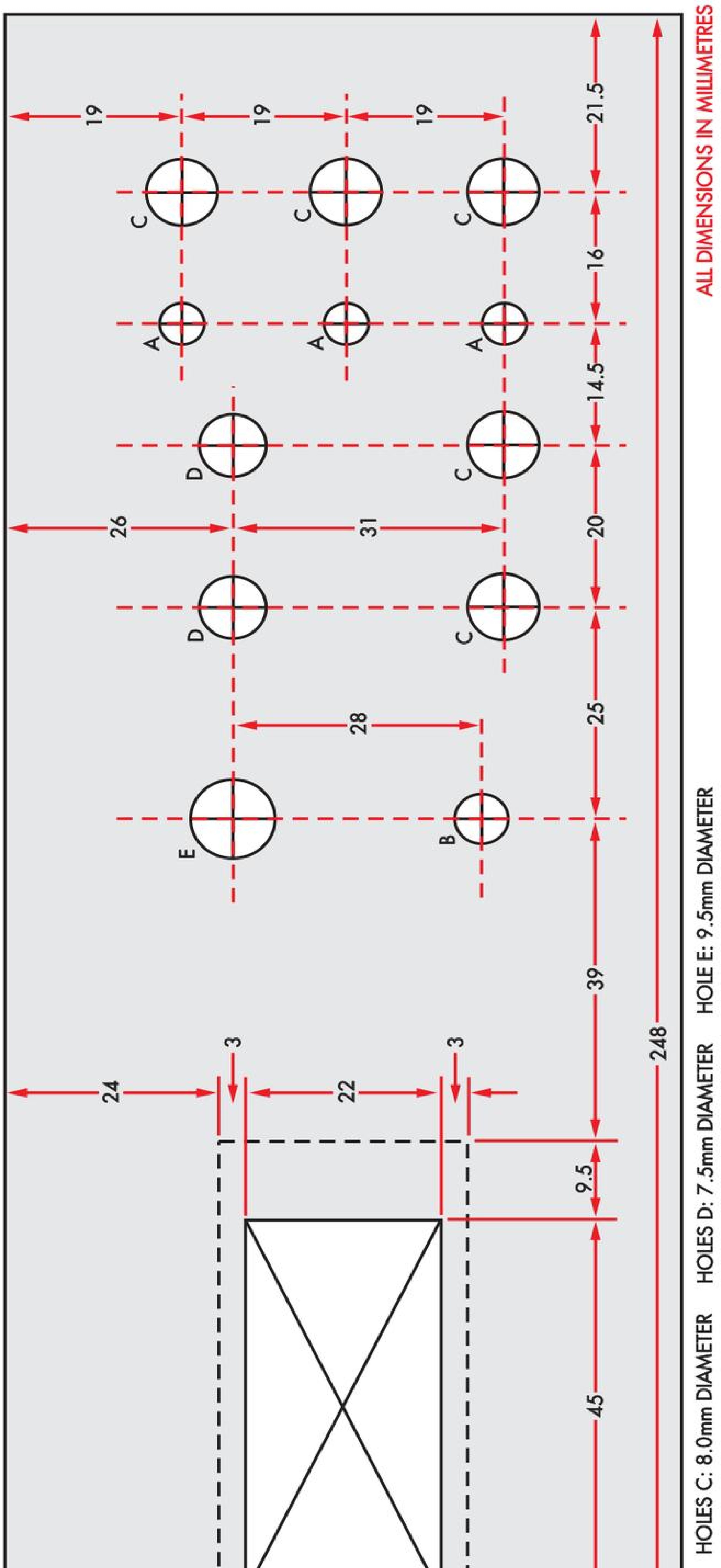
4) Turn the rotary switch clockwise one step to V–, then move the positive multimeter lead to the V– (blue) binding post and adjust VR6 until the display reading matches that on the multimeter.
5) Turn the rotary switch clockwise to V±, connect the DMM between the V+ (red) and V– (blue) binding posts and adjust VR7 until the reading on the panel meter matches that on the multimeter. **If VR7 has insufficient range to properly trim the V± reading, either increase its 68Ω shunt resistor or remove the shunt resistor.**

That completes the setting-up procedure. You can now install the lid and attach the two machine screws which hold it in place.

Using the supply

When using the unit, switch the display selector to either V+ or V– to adjust the output voltage. This can be done with the load switch on or off. To adjust the


DUAL TRACKING SUPPLY
Power
+V
-V
+I
-I
±V
Lim
Display
Load Off
Load On
Voltage Set
+5V
Current Set
+ Limit
Dropout
- Limit
+Vout
0V
-Vout


A
B
C
D
E
19
19
19
26
31
28
24
3
22
3
38
38
21.5
16
14.5
20
25
39
9.5
45
9.5
28
20
248
ALL DIMENSIONS IN MILLIMETRES
HOLES A: 5.0mm DIAMETER
HOLE B: 6.0mm DIAMETER
HOLES C: 8.0mm DIAMETER
HOLES D: 7.5mm DIAMETER
HOLE E: 9.5mm DIAMETER

current limit, switch the display selector to LIMIT and turn the second knob until the desired limit current is indicated on the display.

During use, the current drawn from either output can be viewed by switching the display selector between the I+ and I– positions. If the current limit is exceeded, the corresponding Limit LED will light. Switching the display to V+ or V– shows how far the voltage has dropped to enforce the current limit.

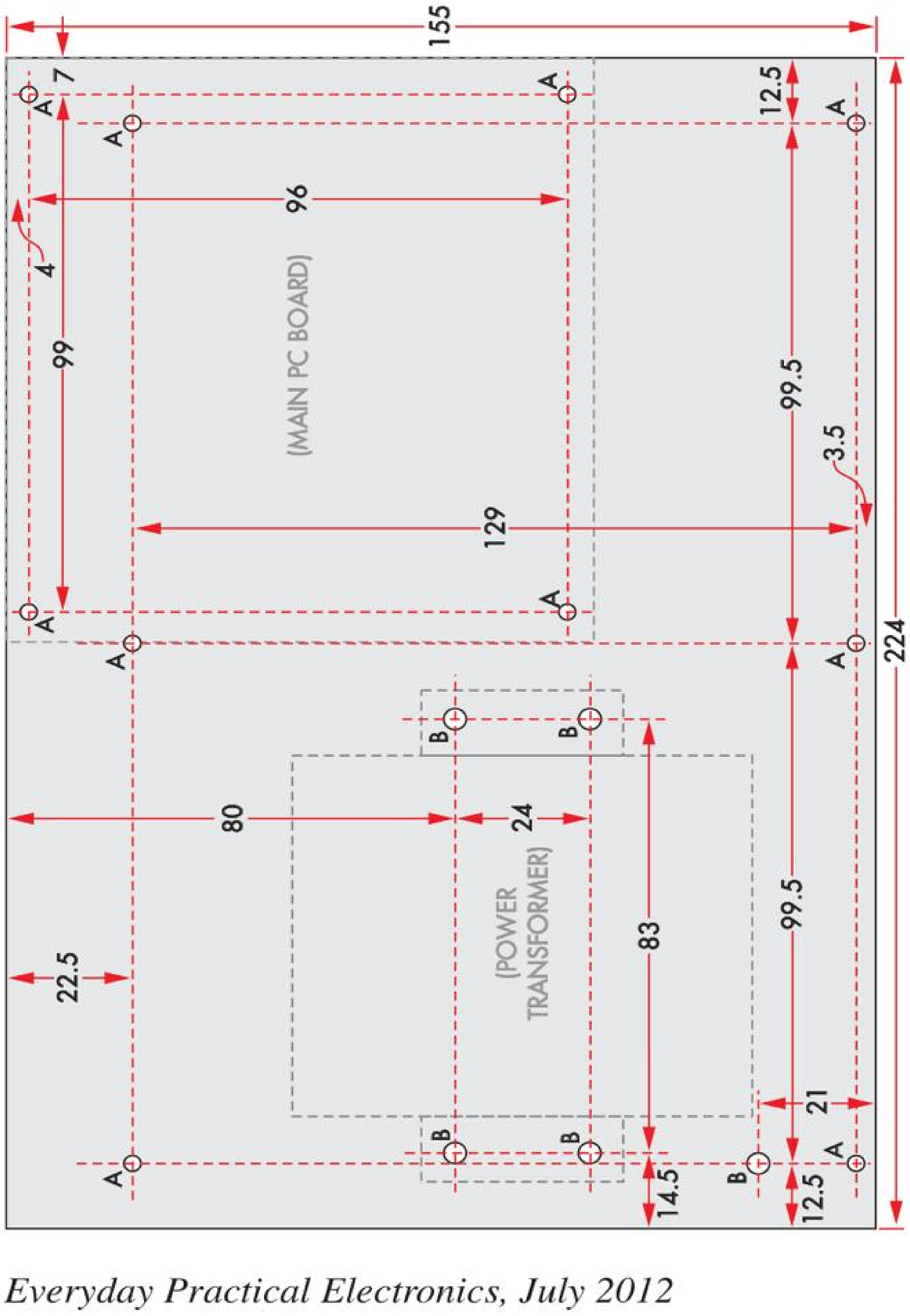
For higher voltage outputs, select the V± readout and adjust the voltage control as required. The load should be connected between the V+ (red) and V– (blue) terminals. The current limit will operate as normal, although only one current-limit LED may light due to slight differences in the op amps or the current-sense trimming.

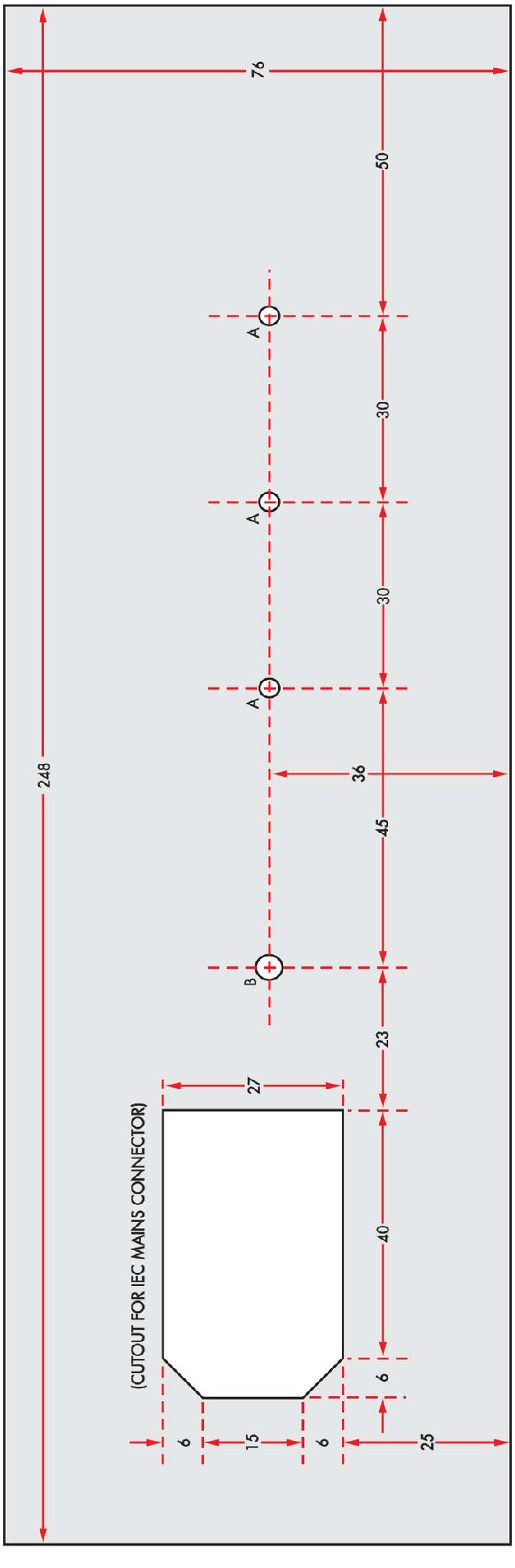
If more current is drawn from the output than is available at the set voltage (see the load graphs published last month), the red dropout LED will light. This indicates that the output voltage is fluctuating. To resume proper regulation, reduce the voltage and/or current until the LED goes out.

The dropout LED can also light if the load impedance varies rapidly.

Finally, under some conditions, if the supply is switched off then on again soon after, the negative output current sense display may not operate correctly. **To solve this, connect a 1N4148 or 1N4004 diode between the output of IC2a and ground, with the anode to ground.**

This diode can either be soldered to the underside of the main PC board or to the electrically connected pads on the rear of the front panel board. ***EPE***





HOLES A: 3.0mm DIAMETER (REGULATOR MOUNTING)
HOLE B: 4.0mm DIAMETER (EARTH LUG MOUNTING)

ALL DIMENSIONS IN MILLIMETRES

MAINS POWERED SUPPLY: REAR PANEL CUTTING/DRILLING DIAGRAM
(SAME SIZE)

Jump Start

By Mike and Richard Tooley

Design and build circuit projects dedicated to newcomers, or those following courses taught in schools and colleges.

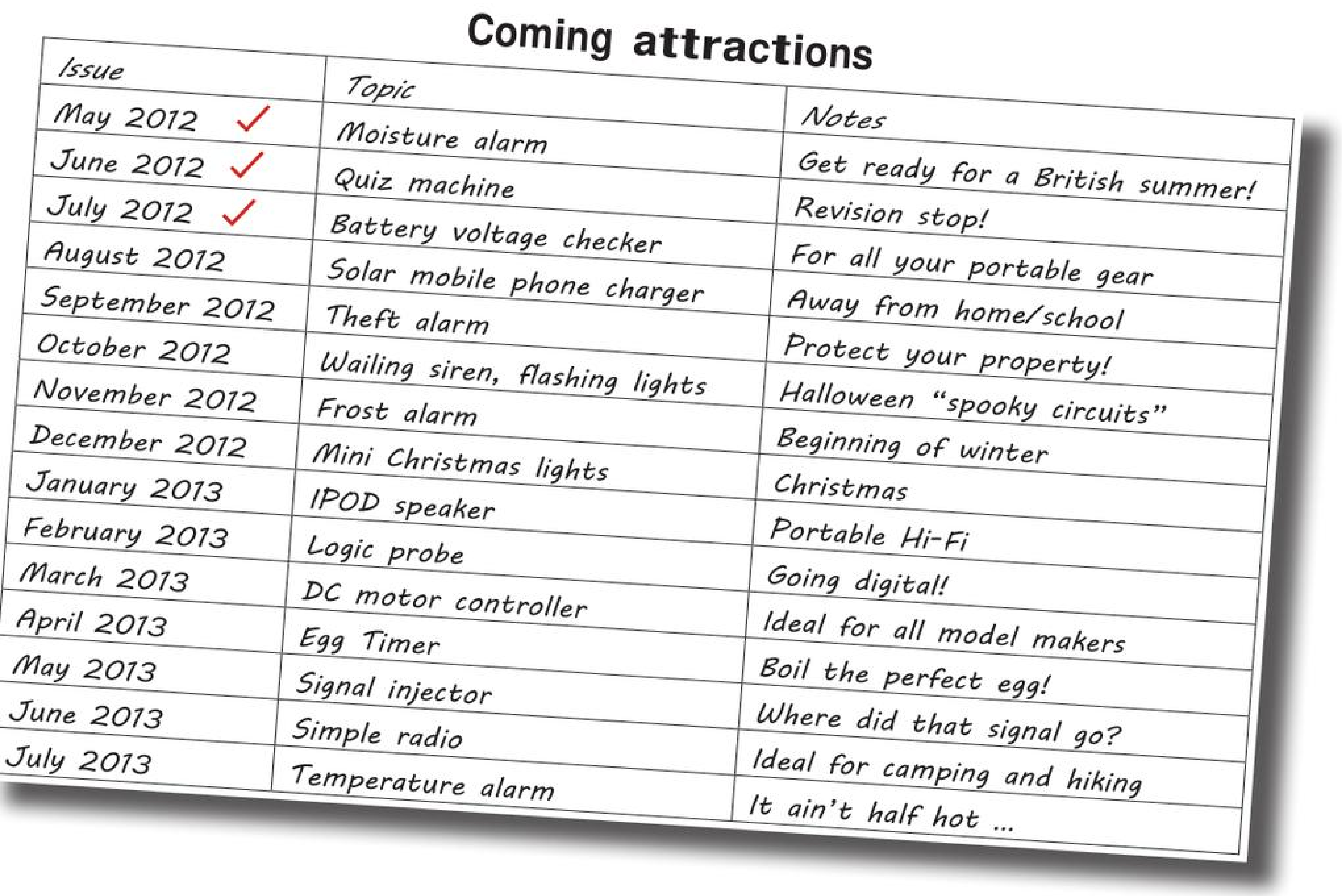
WELCOME to *Jump Start* – our new series of seasonal 'design and build' projects for newcomers. *Jump Start* is designed to provide you with a practical introduction to the design and realisation of a variety of simple, but useful, electronic circuits. The series will have a seasonal flavour, and is based on simple, easy-build projects that will appeal to newcomers to electronics, as well as those following formal courses taught in schools and colleges.

Each part uses the popular and powerful 'Circuit Wizard' software package as a design, simulation and printed circuit board layout tool. For a full introduction to Circuit Wizard, readers should look at our previous *Teach-In series*, which is now available in book form from Wimborne Publishing (see *Direct Book Service* pages 75-77 in this issue).

Each of our Jump Start *circuits include the following features:*

- ***Under the hood*** – provides a little gentle theory to support the general principle/theory behind the circuit involved
- ***Design notes*** – has a brief explanation of the circuit, how it works and reasons for the choice of components
- ***Circuit Wizard*** – used for circuit diagrams and other artwork. To maximise compatibility, we have provided two different versions of the Circuit Wizard files; one for the education version and one for the standard version (as supplied by *EPE*). In addition, some parts will have additional files for download (for example, templates for laser cutting)
- ***Get real*** – introduces you to some interesting and often quirky snippets of information that might just help you avoid some pitfalls
- ***Take it further*** – provides you with suggestions for building the circuit and manufacturing a prototype. As well as basic construction information, we will provide you with ideas for realising your design and making it into a complete project
- ***Photo Gallery*** – shows how we developed and built each of the projects.

Coming attractions



Issue	Topic	Notes
May 2012 ✓	Moisture alarm	Get ready for a British summer!
June 2012 ✓	Quiz machine	Revision stop!
July 2012 ✓	Battery voltage checker	For all your portable gear
August 2012	Solar mobile phone charger	Away from home/school
September 2012	Theft alarm	Protect your property!
October 2012	Wailing siren, flashing lights	Halloween "spooky circuits"
November 2012	Frost alarm	Beginning of winter
December 2012	Mini Christmas lights	Christmas
January 2013	IPOD speaker	Portable Hi-Fi
February 2013	Logic probe	Going digital!
March 2013	DC motor controller	Ideal for all model makers
April 2013	Egg Timer	Boil the perfect egg!
May 2013	Signal injector	Where did that signal go?
June 2013	Simple radio	Ideal for camping and hiking
July 2013	Temperature alarm	It ain't half hot ...

Battery Voltage Checker

In this month's Jump Start *we'll design and build a simple* Battery Voltage Checker *for use when you are 'out and about'.*

Under the hood

Our *Battery Voltage Checker* is designed to check the voltage of a battery used in portable equipment within a nominal voltage range – from 0V to 9V. In order to determine the voltage that appears at the battery's terminals, we need a means of comparing the battery voltage with a known reference voltage using an operational amplifier (otherwise known as an op amp) connected as a *comparator*.

We've not yet met an operational amplifier in *Jump Start*, so it's worth taking a moment to introduce the device and show how it can be used to compare two voltages. Fig.1 shows the symbol for an operational amplifier.

It has two inputs (labelled *inverting* (–) and *non-inverting* (+)) and one output. In addition, there are two supply connections, one of which is

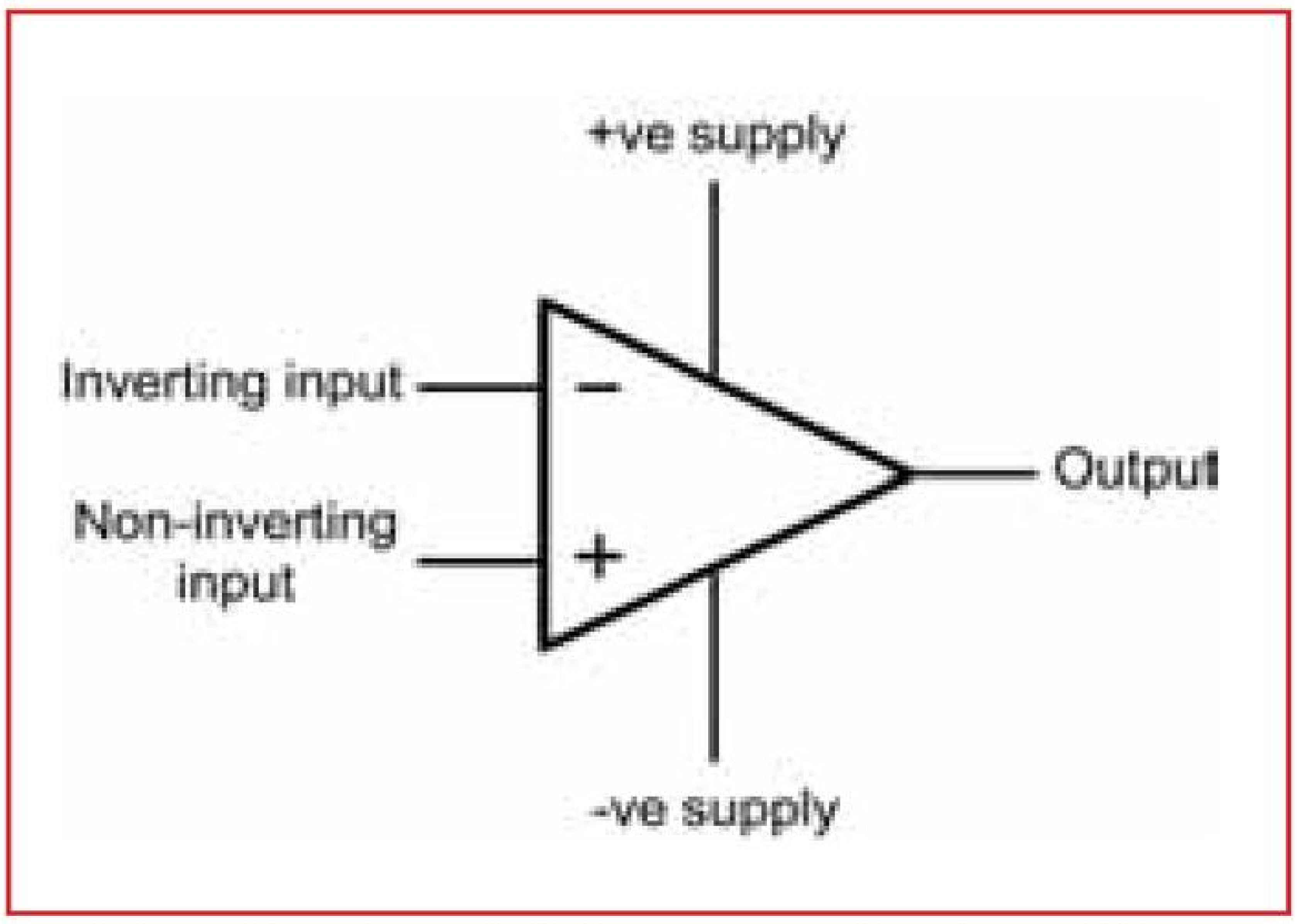


Fig.1. Circuit symbol for an operational amplifier

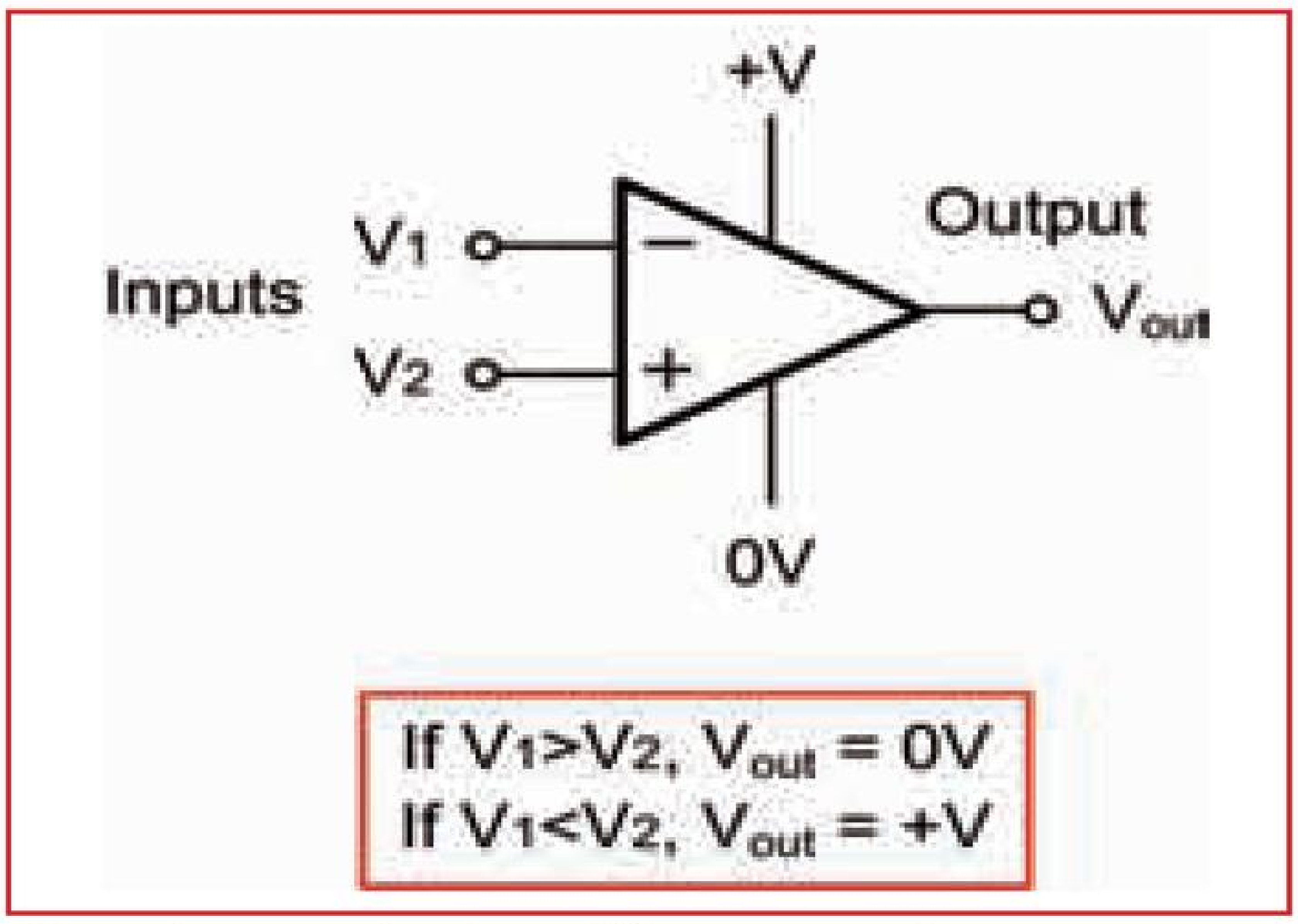


Fig.2. An operational amplifier connected as a comparator

taken to a positive supply, while the other is taken to a negative supply or, in the case of our *Battery Voltage Checker*, to 0V.

Versatile op amp

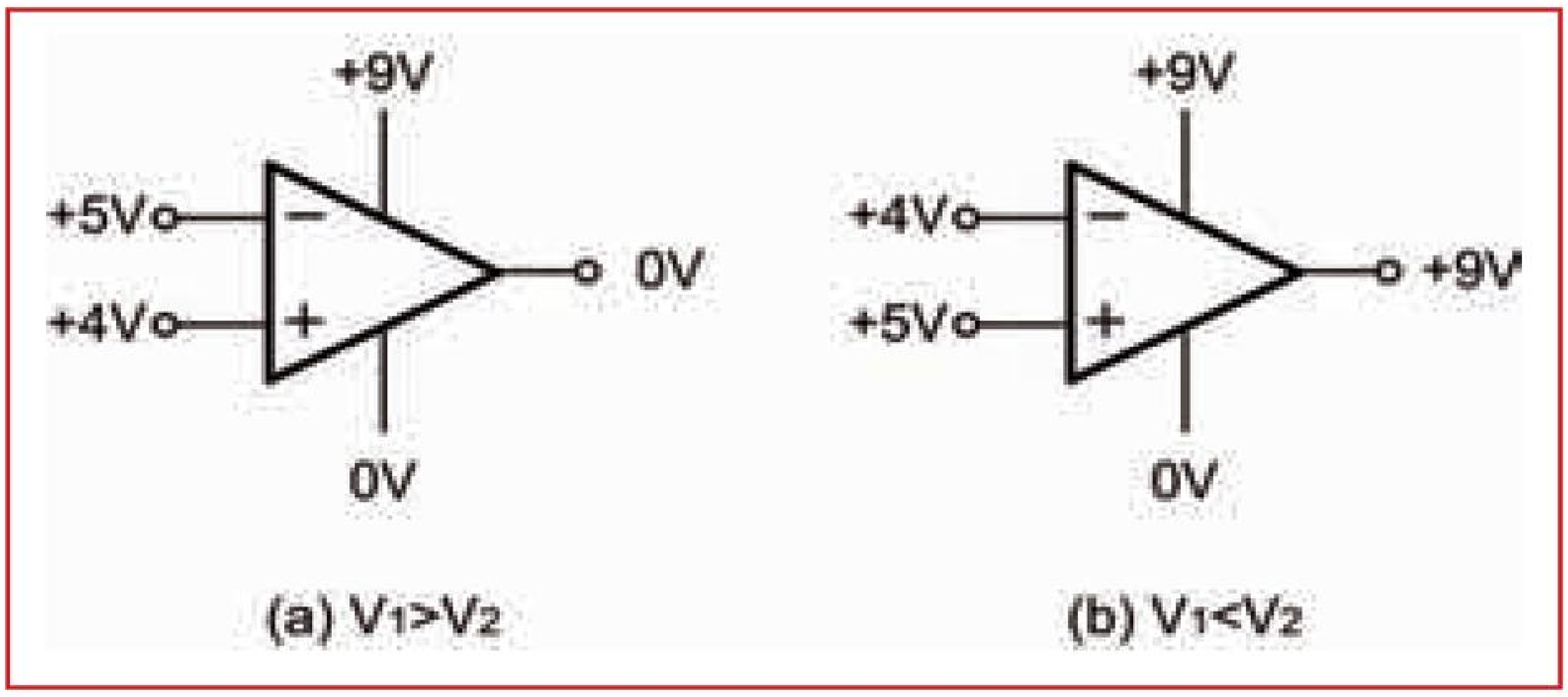
Operational amplifiers are extremely useful and highly versatile components, but one application that they are particularly well suited for is comparing two voltages. In the comparator circuit shown in Fig.2, the output voltage will be either 'low' (close to 0V) or 'high' (approximately equal to the supply voltage, +V) depending on whether the voltage at the inverting input, V1, is greater or less than the voltage at the non-inverting input, V2.

To help explain this behaviour, it's worth looking at a simple example. Fig.3 shows an operational amplifier comparator in which there is a *difference* of +1V (Fig. 3a) or –1V (Fig.3b) in the two input voltages.

Notice how the output voltage is either 0V or +9V, depending on the difference in polarity of the two input voltages. Since operational amplifiers have very high internal voltage gain (typically 100,000 or more) the difference in polarity can be very small in order for the output voltage to change from one level (0V) to the other (+9V).

Get real

You can easily explore the operation of an operational amplifier comparator using Circuit Wizard. Fig.4 shows a good starting point. Here, a variable input voltage is derived from the slider (moving contact) of a potentiometer, VR1. The input voltage is then compared with a reference voltage which is made equal to exactly half the supply voltage by means of the potential divider formed by resistors R1 and R2. With a supply of +9V, the reference voltage is then set at +4.5V and the LED (D1) will become illuminated whenever the input voltage exceeds this value.



(a) V1>V2 (b) V1<V2

Fig.3. Comparator operation with a 9V supply

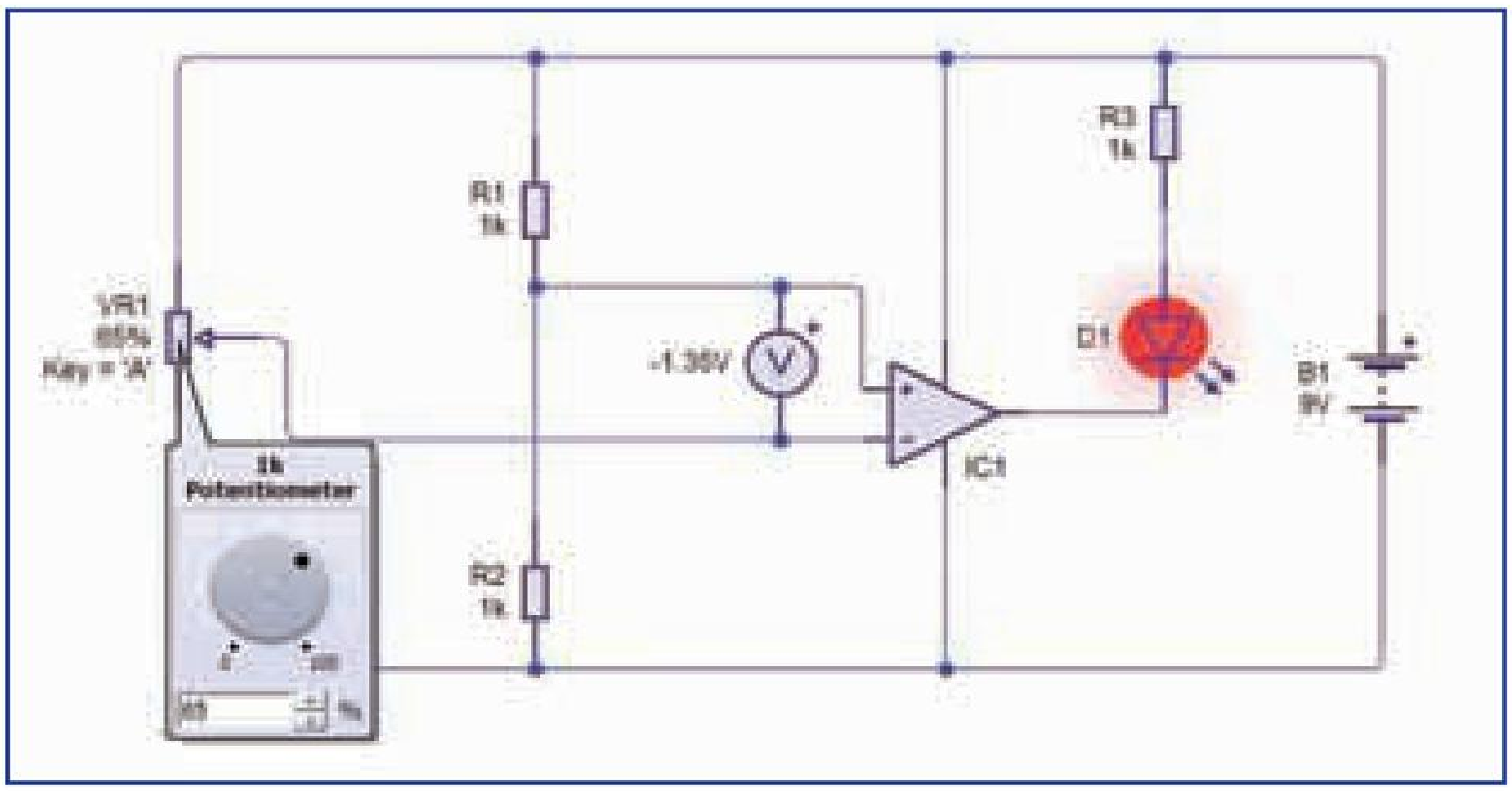


Fig.4. Using Circuit Wizard to examine the operation of a comparator

We have now arrived at a circuit that will indicate that a battery is producing a voltage of at least 4.5V! What we need to do is extend this basic idea so that we can sense a number of different voltage levels. Fig.5 shows how the basic Circuit Wizard arrangement can be extended to sense voltages in three discrete ranges; 0V to 3V (no LED illuminated), 3V to 6V (D2 illuminated), and 6V to 9V(D1 *and* D2 illuminated).

Design notes

To sense ten different voltage levels we are going to need ten comparators, each with a different voltage reference.

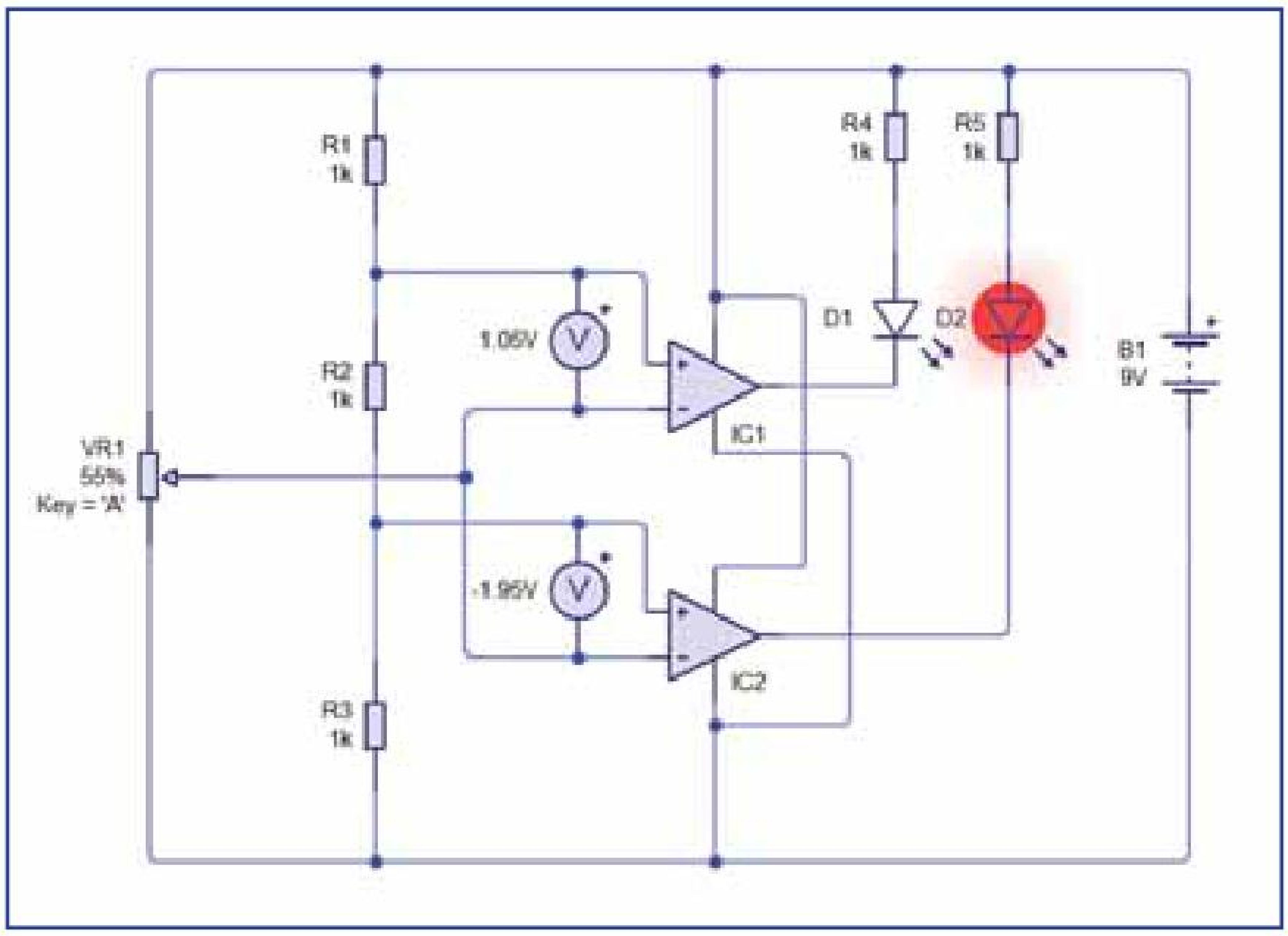


Fig.5. Extending the basic comparator arrangement to sense voltages in three different ranges

Fortunately, semiconductor manufacturers such as Texas Instruments and National Semiconductor have come up with a handy solution in the form of the LM3914 integrated circuit dot/bar display driver.

This useful chip contains ten individual comparator stages, together with an adjustable internal voltage reference and potential divider chain. The LM3914 provides us with a simple and elegant solution packaged in the form of a 20-pin dual-in-line (DIL) chip. Fig.6 shows the simplified internal arrangement of an LM3914.

The LM3914's internal voltage reference (not shown in Fig.6) can be set within the range 1.2V to +12V by selecting appropriate external resistance values. The LED current can also be programmed by a similar choice of external resistance over the range 2mA to 30mA, and the device can be directly interfaced to a seven-segment bargraph display, without the need for any fixed current-limiting resistors.

A note regarding Circuit Wizard versions

Circuit Wizard is available in several variants; Standard, Professional and Education (available to educational institutions only). Please note that the component library, virtual instruments and features available do differ for each variant, as do the licensing limitations. Therefore, you should check which is relevant to you before purchase. During the Jump Start *series we aim to use circuits/features of the software that are compatible with the latest versions of all variants of the software. However, we cannot guarantee that all items will be operational with every variant/version.*

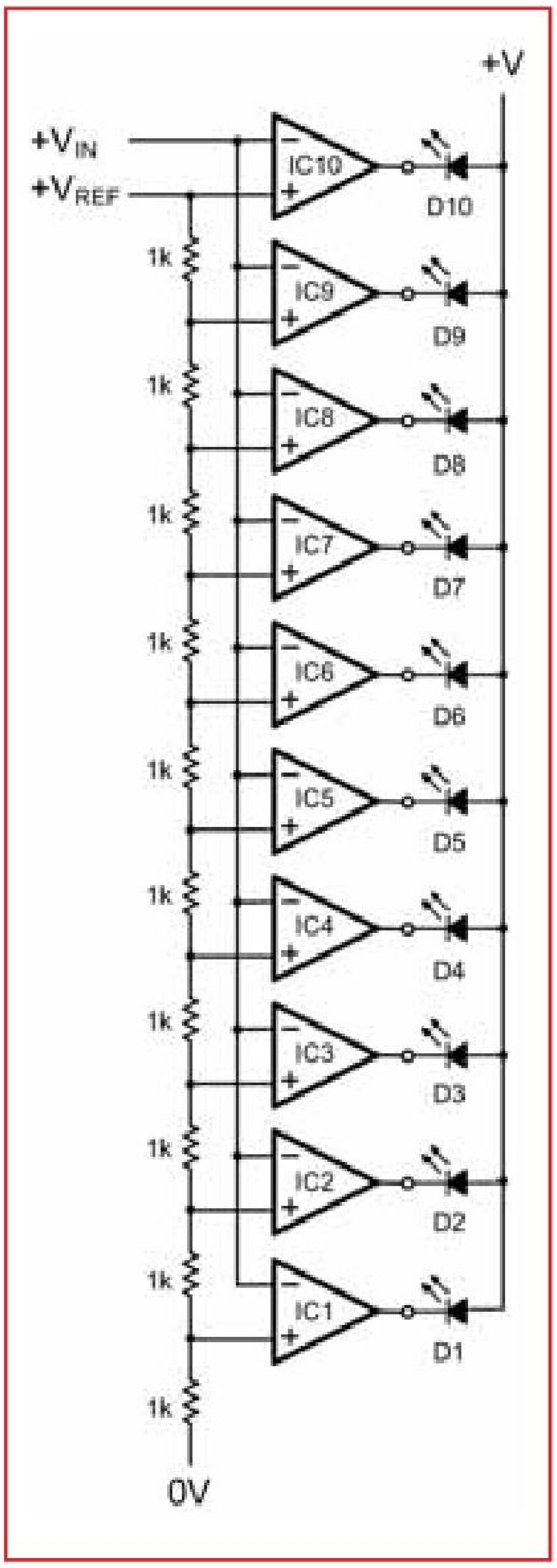


Fig.6. Simplified internal arrangement of an LM3914 showing the ten individual operational amplifier comparator stages

CIRCUIT WIZARD

By integrating the entire design process, Circuit Wizard provides you with all the tools necessary to produce an electronics project from start to finish – even including on-screen testing of the PCB prior to construction!

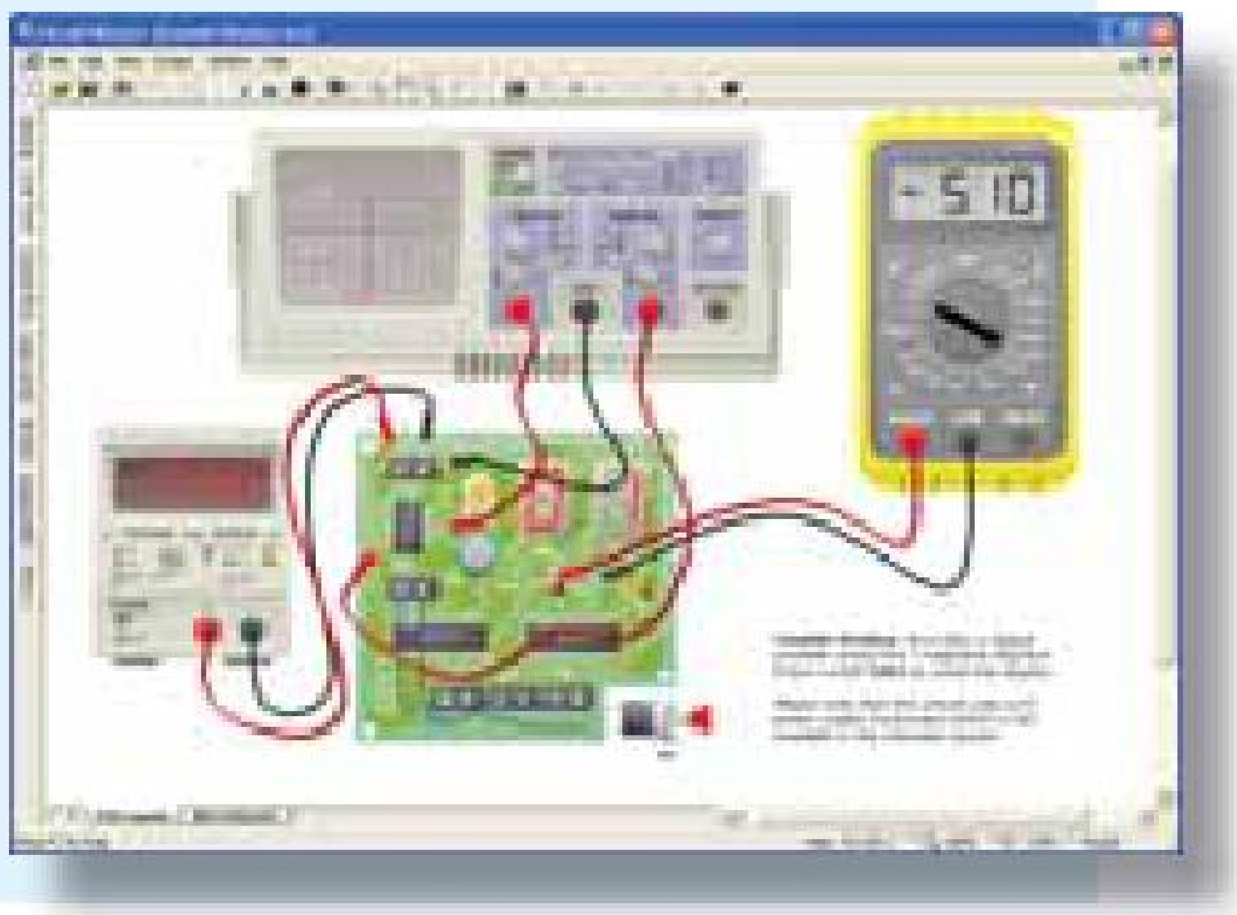
Circuit Wizard is a revolutionary new software system that combines circuit design, PCB design, simulation and CAD/CAM manufacture in one complete package.

Order direct from us on 01202 880299

- *Circuit diagram design with component library (500 components Standard, 1500 components Professional)*
- *Virtual instruments (4 Standard, 7 Professional)*
- *On-screen animation*
- *Interactive circuit diagram simulation*
- *True analogue/digital simulation*
- *Simulation of component destruction*
- *PCB Layout*
- *Interactive PCB layout simulation*
- *Automatic PCB routing*
- *Gerber export*
- *Multi-level zoom (25% to 1000%)*
- *Multiple undo and redo*
- *Copy and paste to other software*
- *Multiple document support*

This software can be used with the *Jump Start* and *Teach-In 2011* series (and the *Teach-In 4* book).

Standard **£61.25** inc. VAT Professional **£91.90** inc. VAT



Battery Voltage Checker – using Circuit Wizard

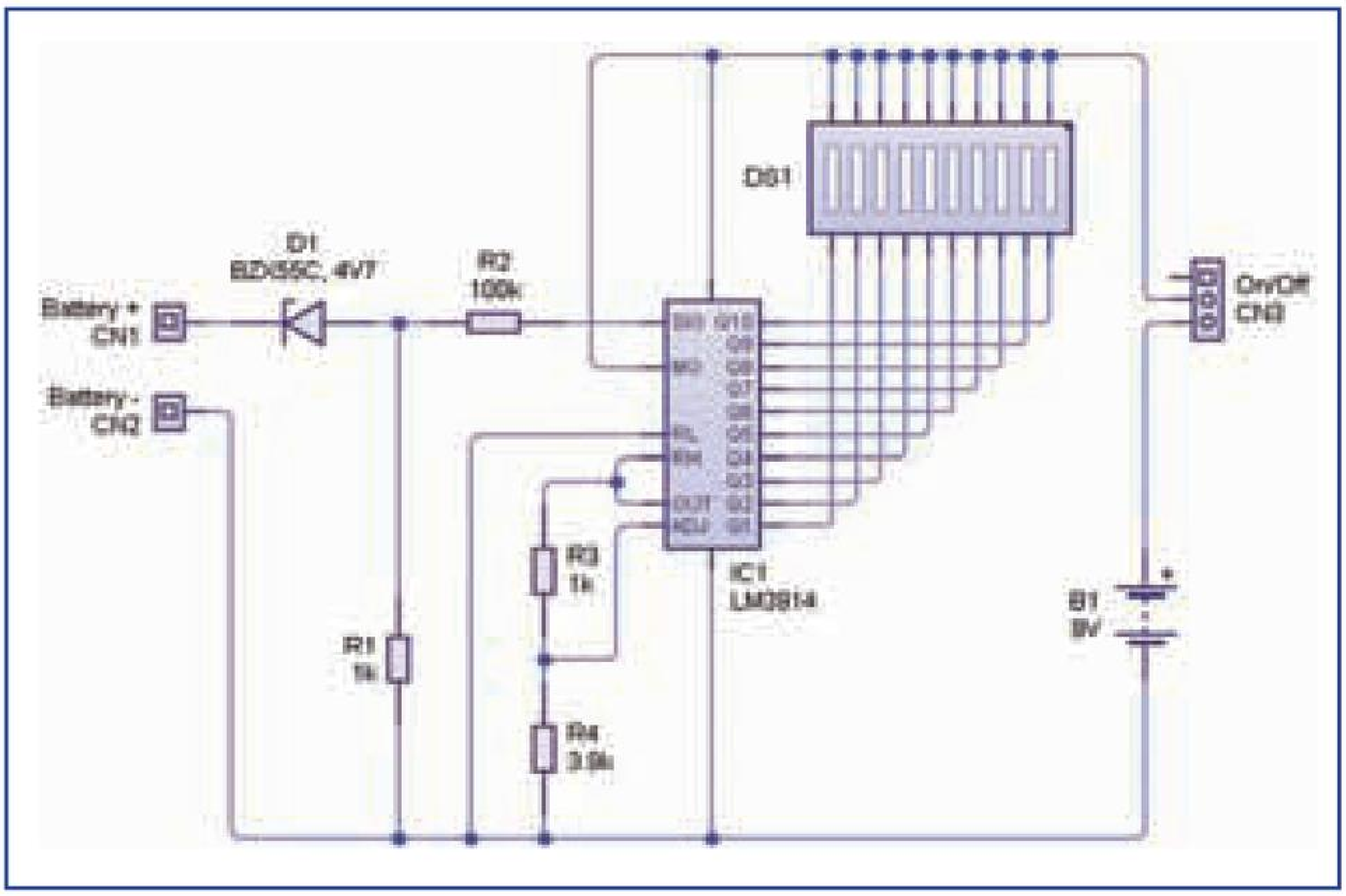
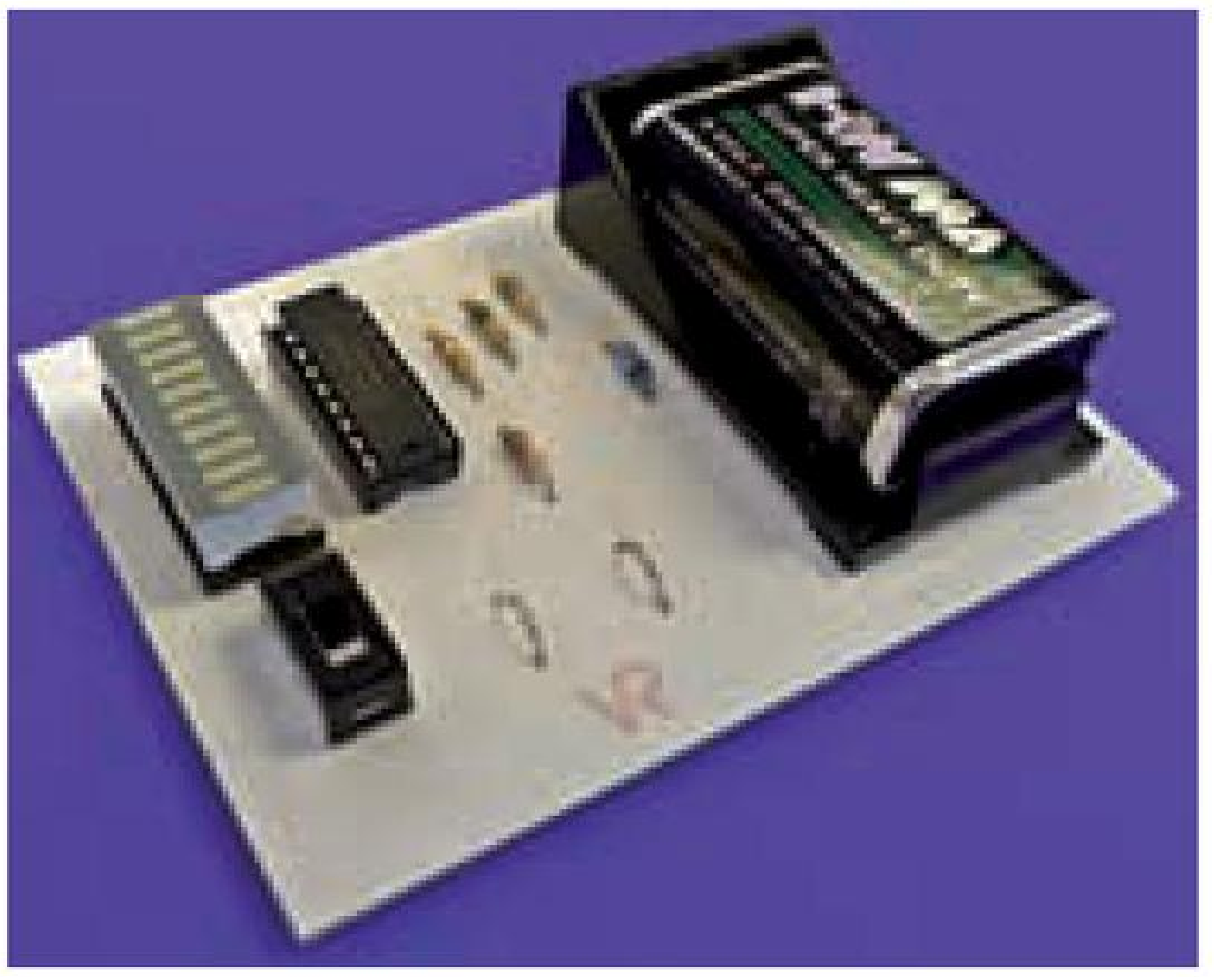

DS1
D1
BZX55C, 4V7
R2
100k
Battery +
CN1
Battery -
CN2
On/Off
CN3
SIG
RLO
RL
RH
OUT
ADJ
Q10
Q9
Q8
Q7
Q6
Q5
Q4
Q3
Q2
Q1
IC1
LM3914
R3
1k
R1
1k
R4
3.9k
B1
9V
+

Fig.7. Circuit diagram of the Battery Voltage Checker



AS WITH all of our *Jump Start* circuits, we've given you the underpinning theory, putting it into practice using circuit simulation and converting it to a PCB design. The Circuit Wizard software that we've used throughout the series makes this process really simple and great fun, and we always recommend following the tutorials to enter the circuits and converting them to your very own PCB designs.

However, if this isn't your bag, you can simply use our artwork to prepare your boards or download our own Circuit Wizard files from the *Jump Start* website at: **www.tooley.co.uk/epe** – Don't forget, if you'd just prefer a pre-made PCB, you can purchase these from the *EPE* Magazine PCB Service (see page 78).

Circuit Wizard

As this month's circuit is nice and simple, we're going to look a little more deeply at the process of making your own PCB layout rather than relying on the auto-route facility. Auto-routing is a great feature and can save you lots of time.

With a little effort (and sometimes a few sneaky tricks) you can achieve a much better result by designing your own track layout. Similarly, there are times when the software just can't figure out a sensible layout by itself, so we need to get a bit more involved with the process.

As usual, start by carefully entering the schematic shown in Fig.7. Note that we've included a three-pin single in-line (SIL) connector (CN3) – this is actually for a PCB-mounting slide switch that has this package style.

In order to test the circuit operation, we'll need to add a temporary link to simulate the switch being closed as well as adding a variable voltage input voltage (V1) to simulate the battery on test. Run the simulation (Fig.8) and experiment with varying the input voltage.

Once you're happy with the operation of the circuit, we can go ahead and design our PCB layout... but don't forget to remove the input voltage and CN3 link first!

You will need...

1 PCB, code 858, available from the *EPE PCB Service,* size 90mm × 60mm
1 PP3 PCB mounting battery holder
1 20-pin DIL socket
1 18-pin DIL socket
1 SPDT miniature toggle switch

Semiconductors
1 BZX55C 4V7 Zener diode (D1)
1 Common-anode 10-segment red LED bar display
1 LM3914 dot/bar display driver

Resistors
2 1kΩ (R1, R3)
1 100kΩ (R2)
1 3.9kΩ (R4)

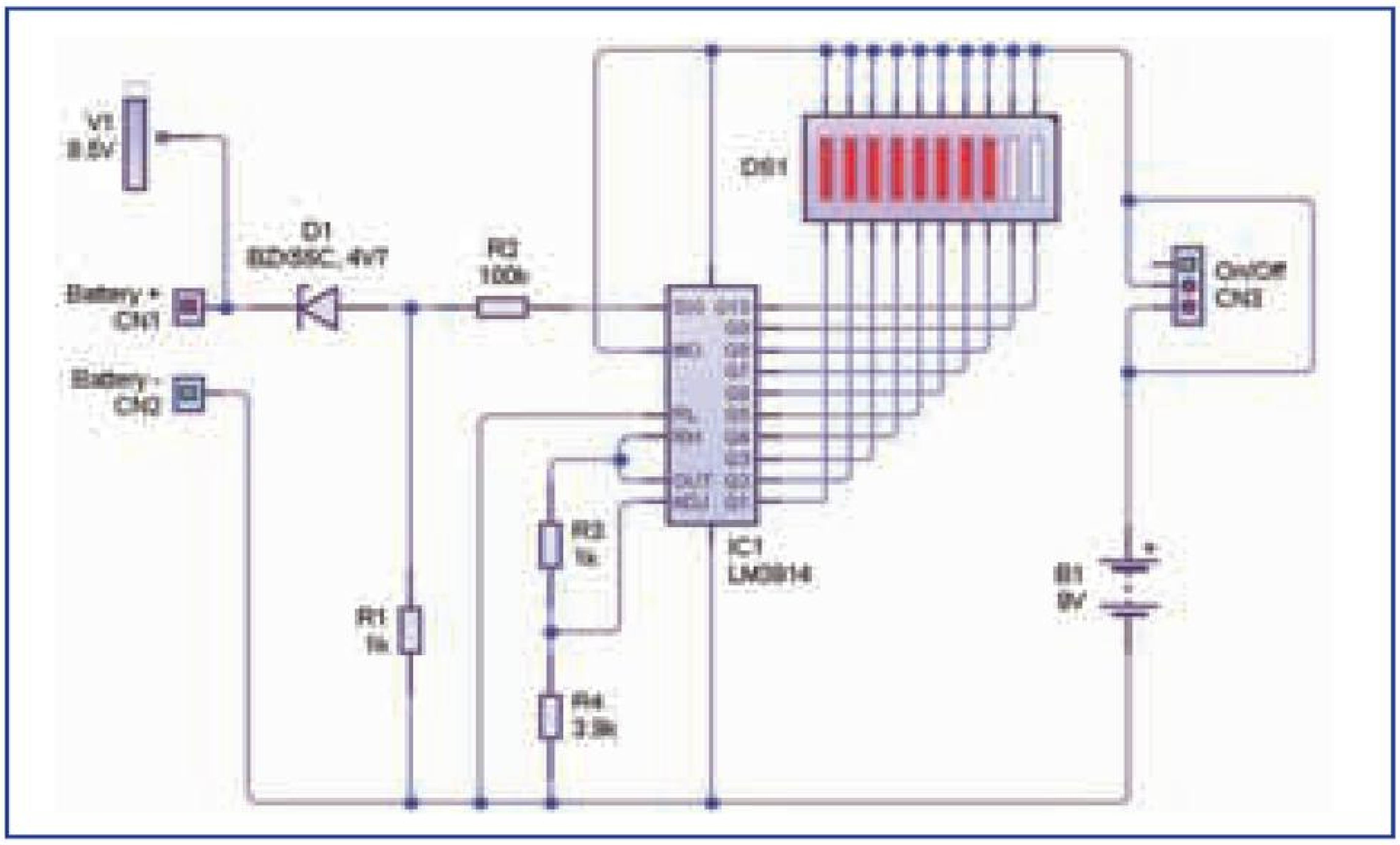
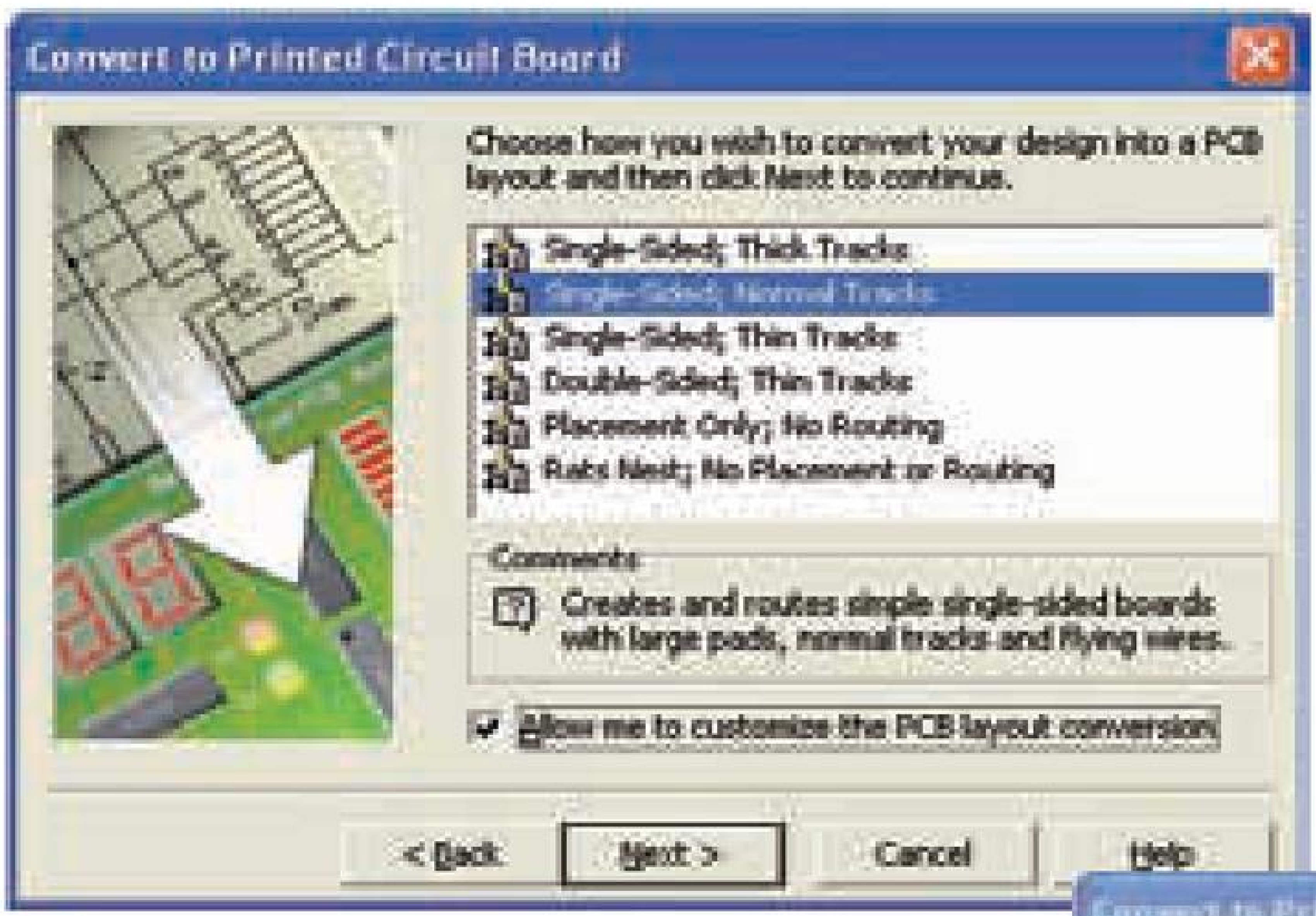

V1
8.5V
DS1
D1
BZX55C, 4V7
R2
100k
Battery +
CN1
Battery -
CN2
On/Off
CN3
SIG
RLO
RL
RH
OUT
ADJ
Q10
Q9
Q8
Q7
Q6
Q5
Q4
Q3
Q2
Q1
IC1
LM3914
R3
1k
R1
1k
R4
3.9k
B1
9V
+

Fig.8. Circuit simulation of the Battery Voltage Checker using Circuit Wizard

Printed ciruit board production

To begin the manual PCB design process, start the PCB 'Convert to PCB Layout' wizard (by either clicking the icon on the toolbar or selecting Project > Circuit Symbols > Convert to PCB Layout…). Select 'Single-Sided; Normal Tracks' and check the 'Allow me to customise the PCB Layout conversion' box (see Fig.9).



Convert to Printed Circuit Board

Choose how you wish to convert your design into a PCB layout and then click Next to continue.

- Single-Sided; Thick Tracks
- Single-Sided; Normal Tracks
- Single-Sided; Thin Tracks
- Double-Sided; Thin Tracks
- Placement Only; No Routing
- Rats Nest; No Placement or Routing

Comments

Creates and routes simple single-sided boards with large pads, normal tracks and flying wires.

☑ Allow me to customize the PCB layout conversion

Fig.9. First stage of circuit conversion to a PCB layout

The next step allows you to specify the size of the PCB – just leave this unticked and click 'Next'. On the next step you are provided with a list of the components found in your circuit. By double clicking on a component you can change the physical package that Circuit Wizard will place on your PCB. The software contains a large database of component models and their physical package, so it's pretty accurate at making the right choice of package to include on your PCB for any particular component. For this reason, it's always important that you select the correct component model when you enter your circuit schematic.

The most common time when you are likely to need to change the component package is when you are making a decision as to whether components such as LEDs, switches or batteries are mounted on or off the board. For example, in last month's project we mounted the pushbutton switches on to the PCB itself, so we switched the two-pin terminal block that Circuit Wizard uses as standard for a 6mm PCB-mounting tactile switch.

The only component that we need to alter for our battery tester is the battery. In this case, we are going to use a PCB-mounted PP3 holder. Double-click the 9V Battery (B1) on the list and select 'PP3 Battery with Holder (9V)' from the drop-down (Figure X).

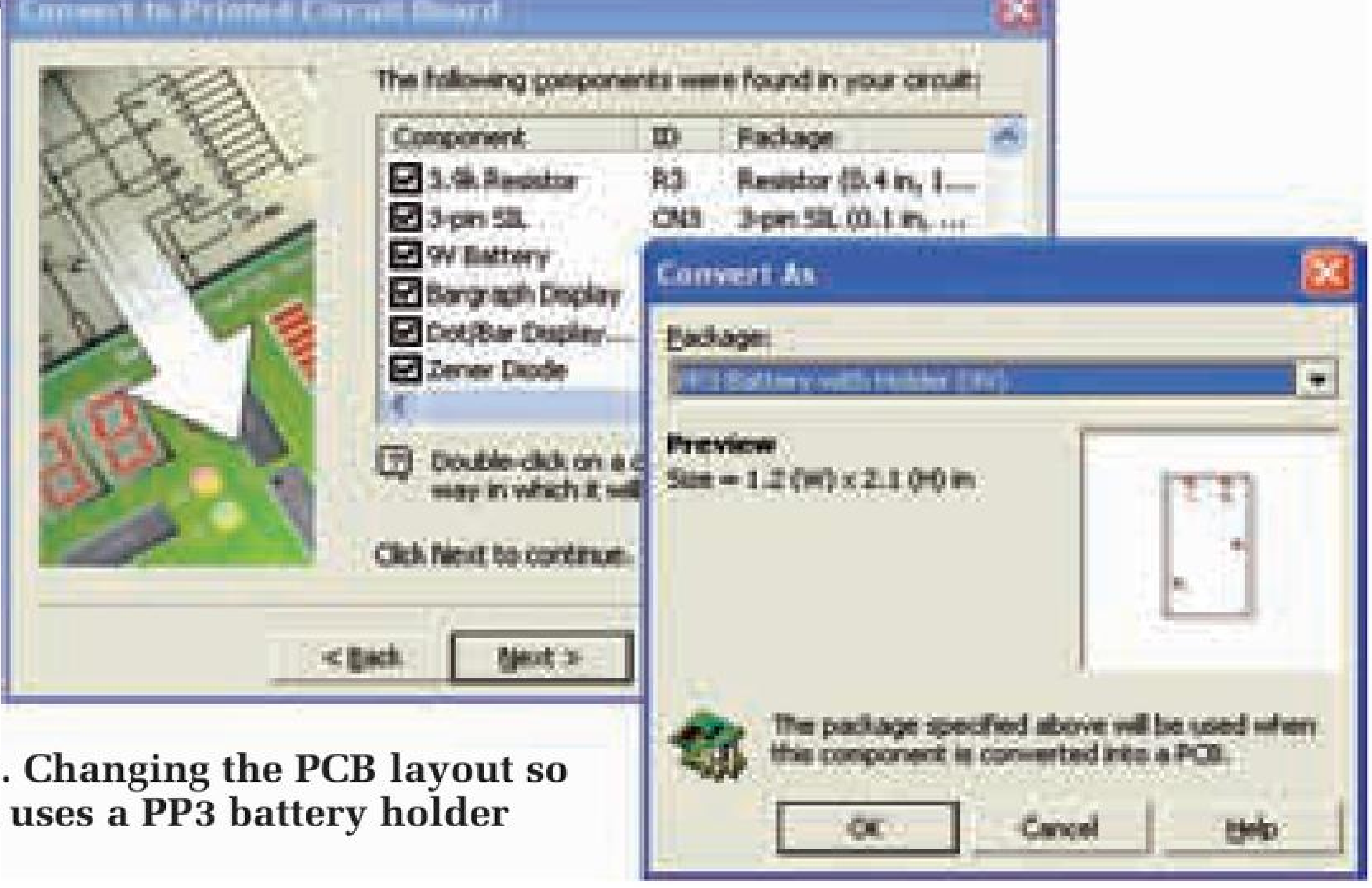
Just a tick

At the next step, untick 'Use Customized component pads' and click Next. You will then be presented with a list of tick boxes asking you what you would like Circuit Wizard to do for you in terms of designing the PCB. We're going to do all of the hard work ourselves today, so un-tick the top item 'Automatically place components on the board' (the tick boxes below will all grey out) then continue to convert your circuit.

You should now be presented with a blank PCB board with your components underneath (Fig.11). You'll notice that the components have thin green lines connected to them. These aren't tracks – they are called 'nets', and they show what connections need to be made on the PCB. They can be really helpful when deciding on the position of the components.

As a general rule, we want to put our components on to the PCB in such a way that the connections (tracks) can be made as easily as possible. Therefore, we want to keep the nets from crossing each other as much as possible, and try to make the required tracks as short and simple as possible.

Where we can't avoid tracks crossing, we can route the track between the pads of components such as resistors – so it's worth thinking about this when placing the components. We can also run tracks through the centre of an integrated circuit. Advanced industrial circuits with very narrow tracks can even run tracks between the pads on an integrated circuit.



Convert to Printed Circuit Board

The following components were found in your circuit:

Component	ID	Package
☑ 3.9k Resistor	R3	Resistor (0.4 in, 1…
☑ 3-pin SIL	CN3	3-pin SIL (0.1 in, …
☑ 9V Battery		
☑ Bargraph Display		
☑ Dot/Bar Display…		
☑ Zener Diode		

Double-click on a c

way in which it wil

Click Next to continue.

Convert As

Package: PP3 Battery with Holder (9V)

Preview

Size = 1.2 (W) x 2.1 (H) in

The package specified above will be used when this component is converted into a PCB.

Fig.10. Changing the PCB layout so that it uses a PP3 battery holder

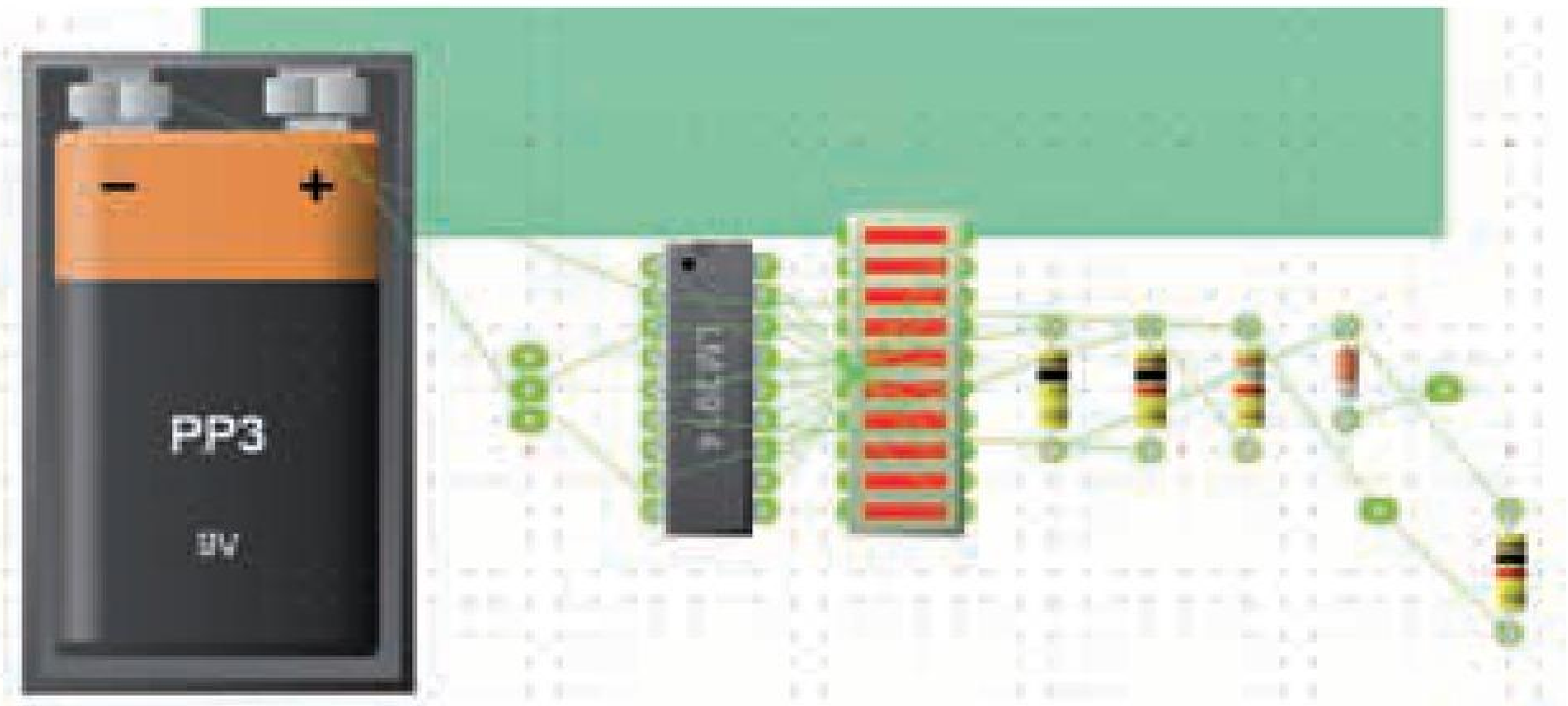


Fig.11. Initial component layout prior to routing

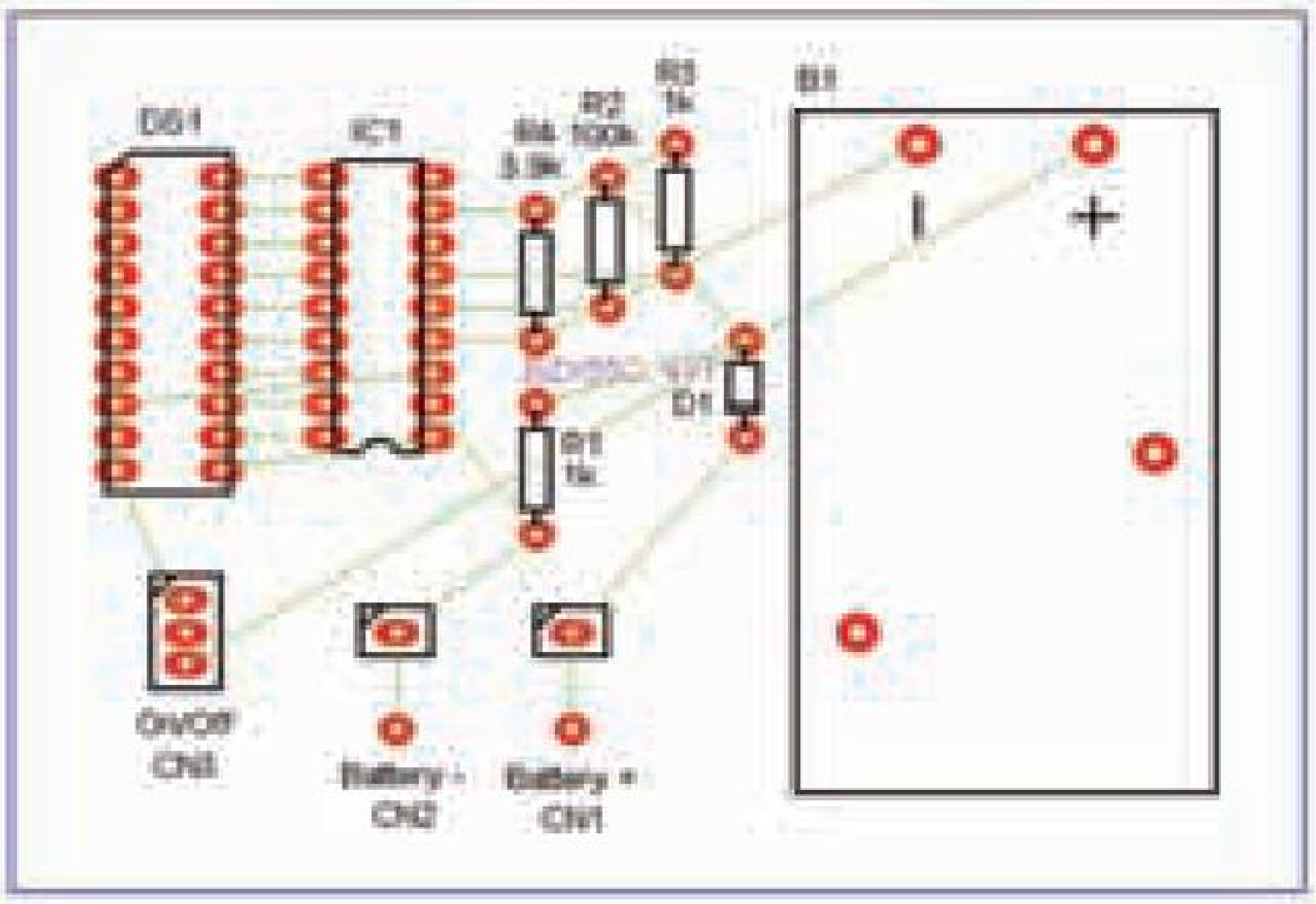


Fig.12. Components arranged ready for tracks (showing connection nets in green)

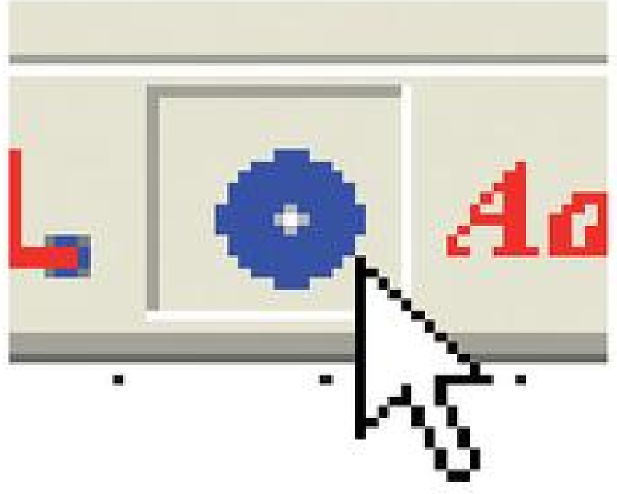


Fig.13. Adding a pad

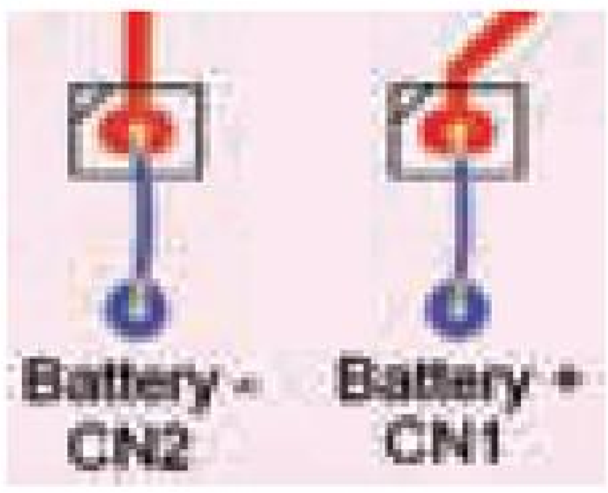


Fig.15. Flying wires connected to the battery pads

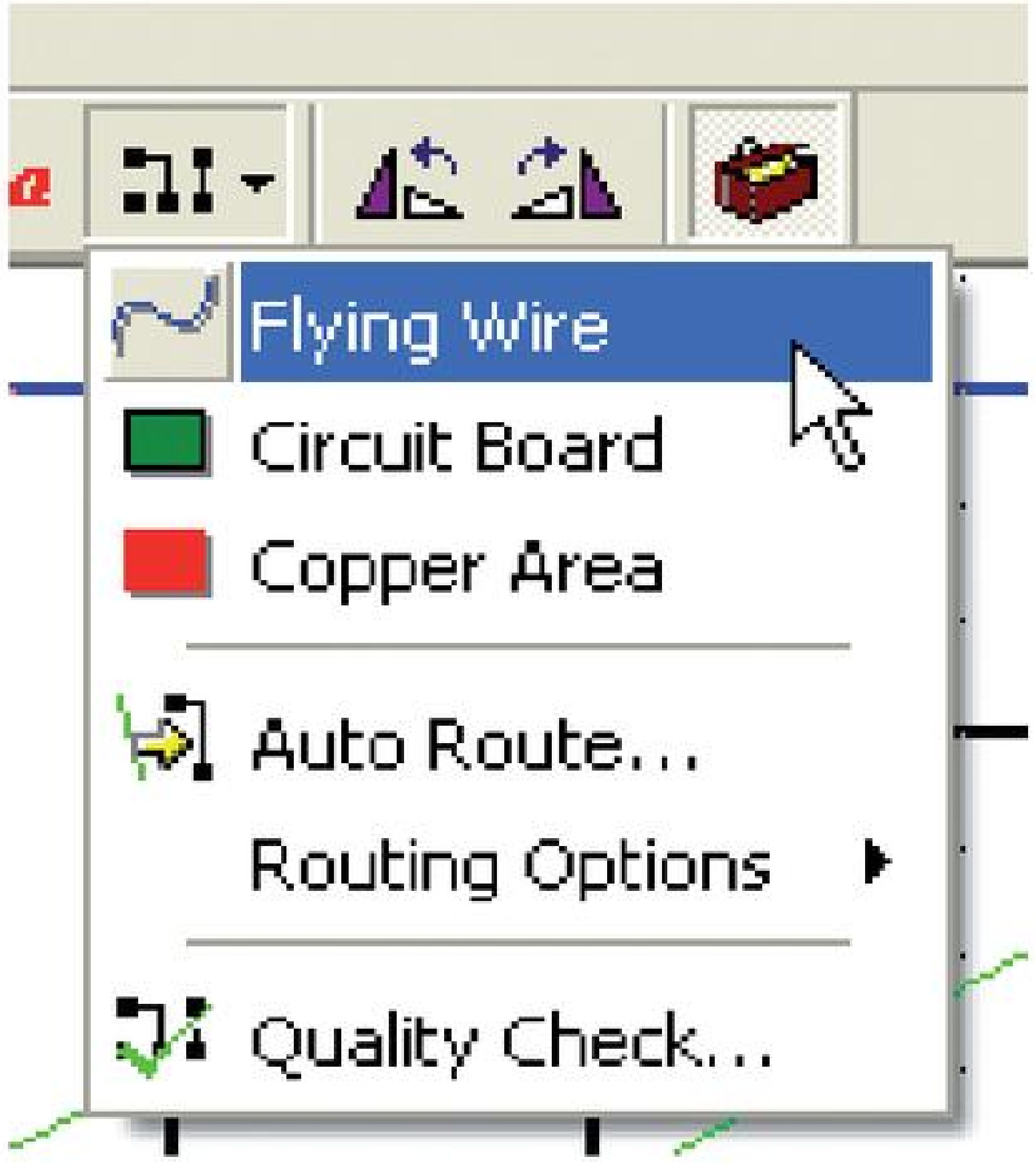


Fig.14. Adding a flying wire

First steps

Right, so let's get on with designing our very own layout. First, we recommend that you change to the 'Normal' view by selecting the tab on the top left. This gives a more traditional design view with tracks in red and the silk screen showing – the pretty component visuals on the 'real world view' do tend to hide the track layout underneath. Start by laying out the components as we described above, trying to simplify the pattern of the green net lines.

With our *Battery Voltage Checker* circuit, the connections we require from the bar display IC and the driver IC will align really nicely, but only when the bar driver chip is upside-down; ie, oppositely orientated to the LED bargraph display.

You can rotate IC1 (or any other component for that matter) by selecting the component and pressing Ctrl+R or by right-clicking and selecting 'Arrange > Rotate Right/Left'. Once you're happy with your component positions, you're ready to start making the connections.

On track

Drawing tracks in Circuit Wizard works very much like many other PCB drawing programmes – although it can be a bit confusing to begin with if you haven't had any previous experience. To draw a track you left-click to start the track, left-click to add a node (eg, a corner), then finally right-click to complete the track.

In this way, a long multi-segment track can be drawn rather than drawing several connecting straight lines. Once a track is drawn, you can edit it by clicking and dragging individual nodes to change the path of the track.

To create two test points, where a PP3 battery can be placed on them for testing, we need to add two wire links. These need to be placed 0.5in apart.

Move CN1 and CN2 so that they are horizontally aligned and 0.5in apart; using the grid dots as a guide they should be five dots apart. Next, add a pad underneath each by using the pad tool (Fig.13).

Finally, add a wire link by clicking on the 'PCB Layout Tools' icon and selecting 'Flying Wire', then draw the link from CN1/2 down to each of the two pads that you've added (Fig.14 and Fig.15).

Quality report

Once you've completed your design, it's always worth carrying out a Quality Report (see Fig.16), as we discussed in last month's *Jump Start*. It's also possible to simulate your PCB design by adding an off-board SPDT switch to CN3 and using a power supply virtual instrument, available in the Pro and Educational versions of Circuit Wizard (see Fig.17). Users of the Standard version of Circuit Wizard can use various combinations of the off-board battery packs to simulate different voltages in order to check the circuit. Once you've made all your checks, you're ready to print your artwork and create your masterpiece.

In our example, we've made a simple laser cut mount for the PCB (CAD files, available for download from our website at: **www.tooley.co.uk/epe**). The design uses 5mm clear

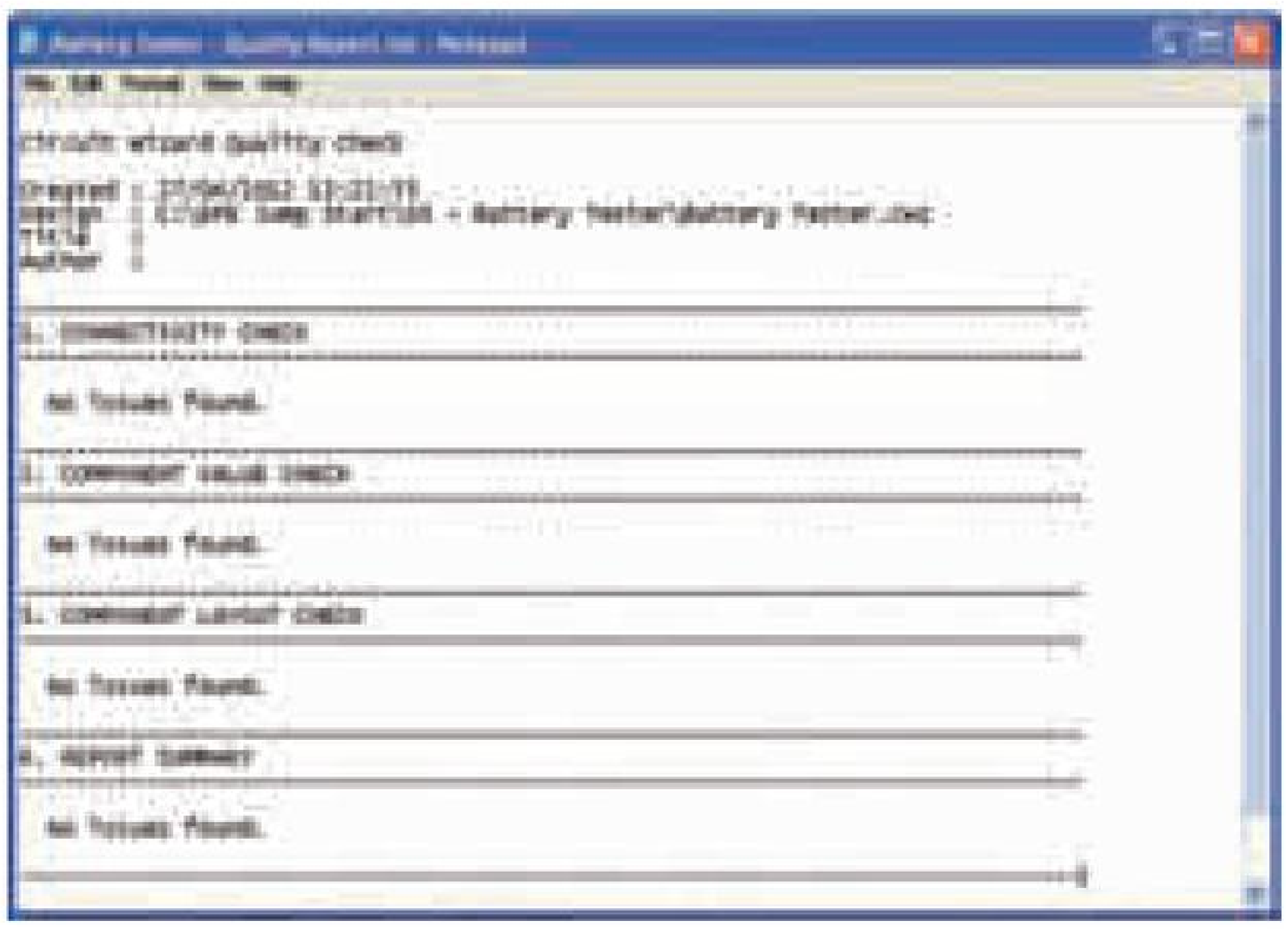


Fig.16. Quality report for the Battery Voltage Checker

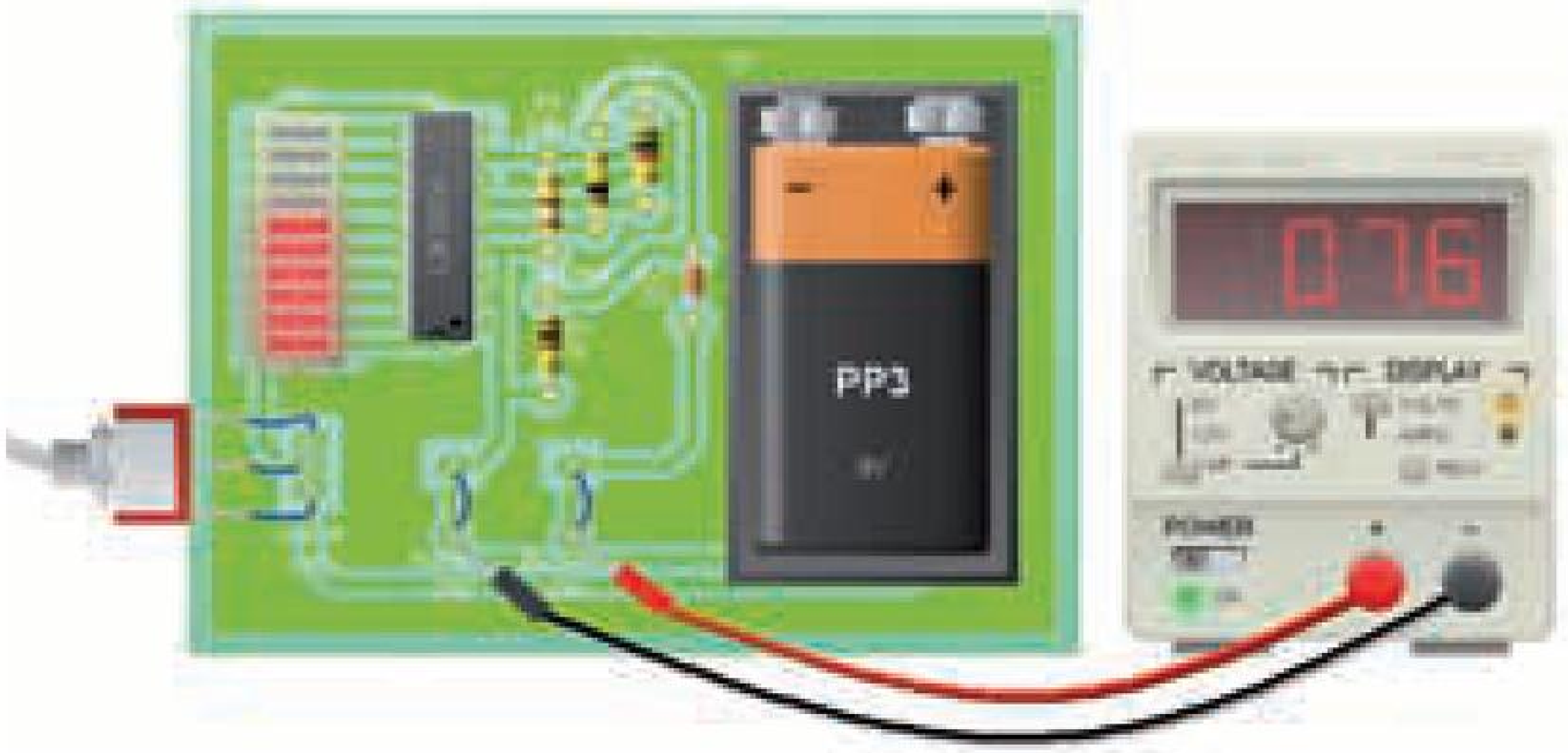


Fig.17. Simulating the circuit with a virtual power supply

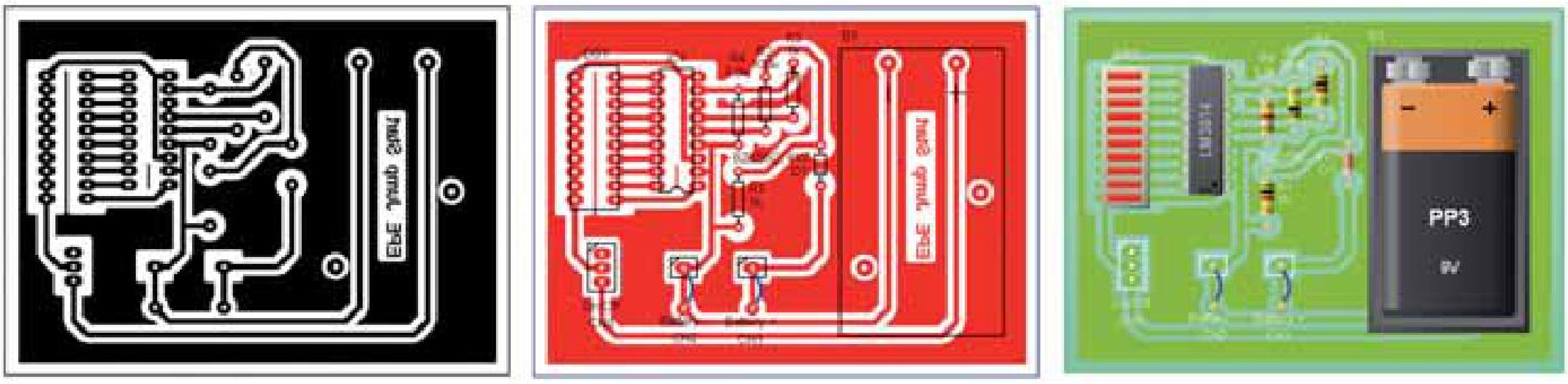


Fig.18. Complete PCB artwork in various views. The final size of the prototype board is 90mm × 60mm

acrylic and with two slots to accept the PCB. A line bender is used to bend the two 'wings' upright. Care should be taken when inserting the PCB, which requires the wings to be gently flexed open to allow it to slot in. The design on the sides may be personalised to suit and engraved mirrored on the inside of the mount.

As with all of the designs featured in the series, it's entirely up to you how your final product looks. Be creative and try out your design skills. Why not send us a picture of your masterpiece: **jumpstart@tooley.co.uk** – we might even feature it in the series.

Next month – We will be developing a *Solar Charger* that can be used to recharge battery-powered equipment, including some types of mobile 'phones.

Photo gallery...

The Gallery is intended to show readers some of the techniques that they can put to use in the practical realisation of a design, such as PCB fabrication and laser cutting. This is very important in an educational context, where learners are required to realise their own designs, ending up with a finished project that demonstrates their competence, skills and understanding. The techniques that we have used are available in nearly every secondary school and college in the country. We believe that our series will provide teachers with a tremendously useful resource!

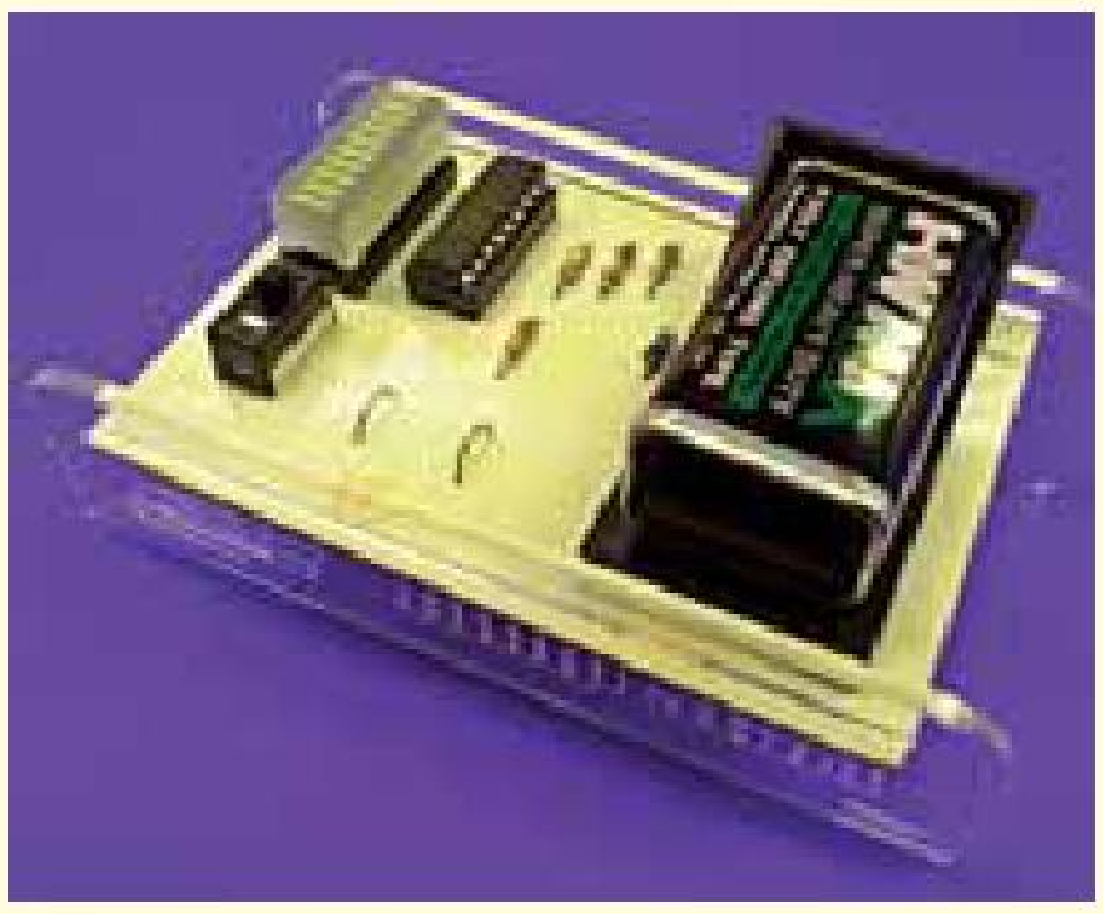
Laser cutting the clear acrylic base

WARNING HOT WIRE

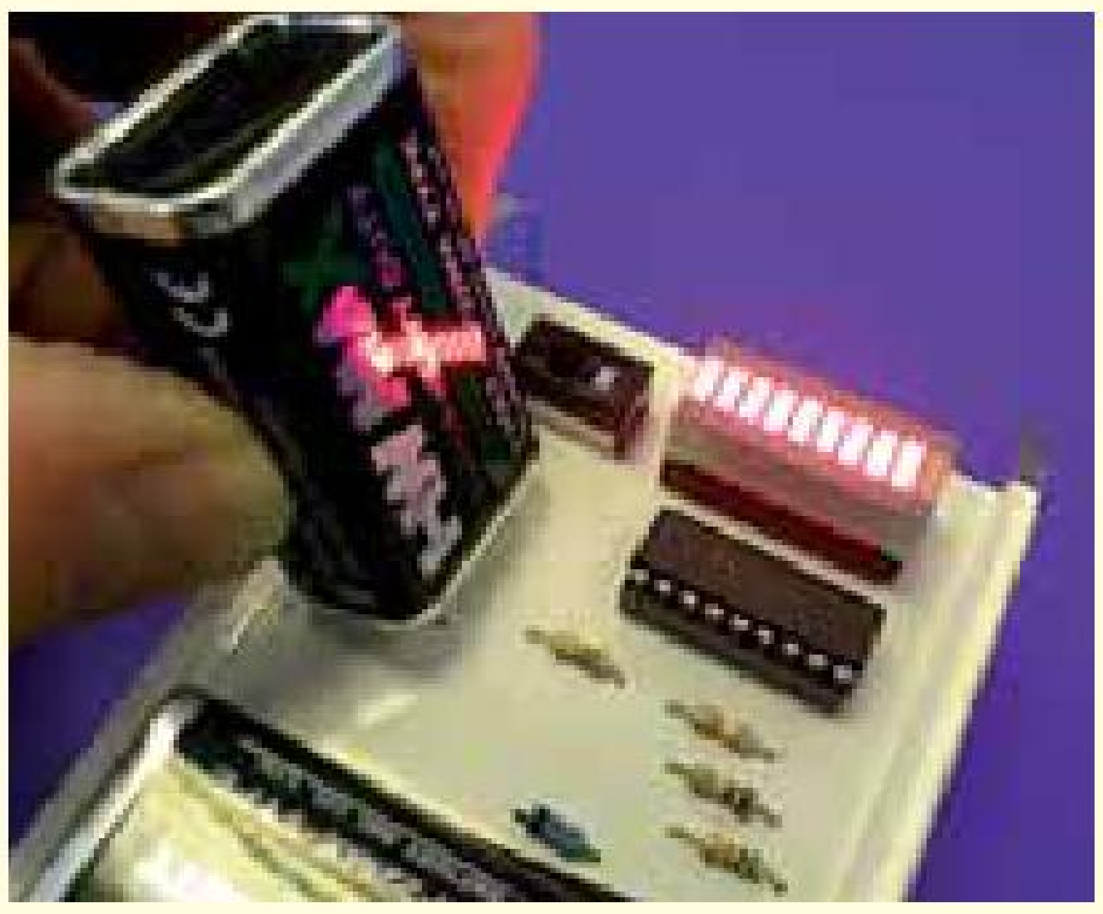
Clear acrylic base being bent using a line bender

EPE Jump Start

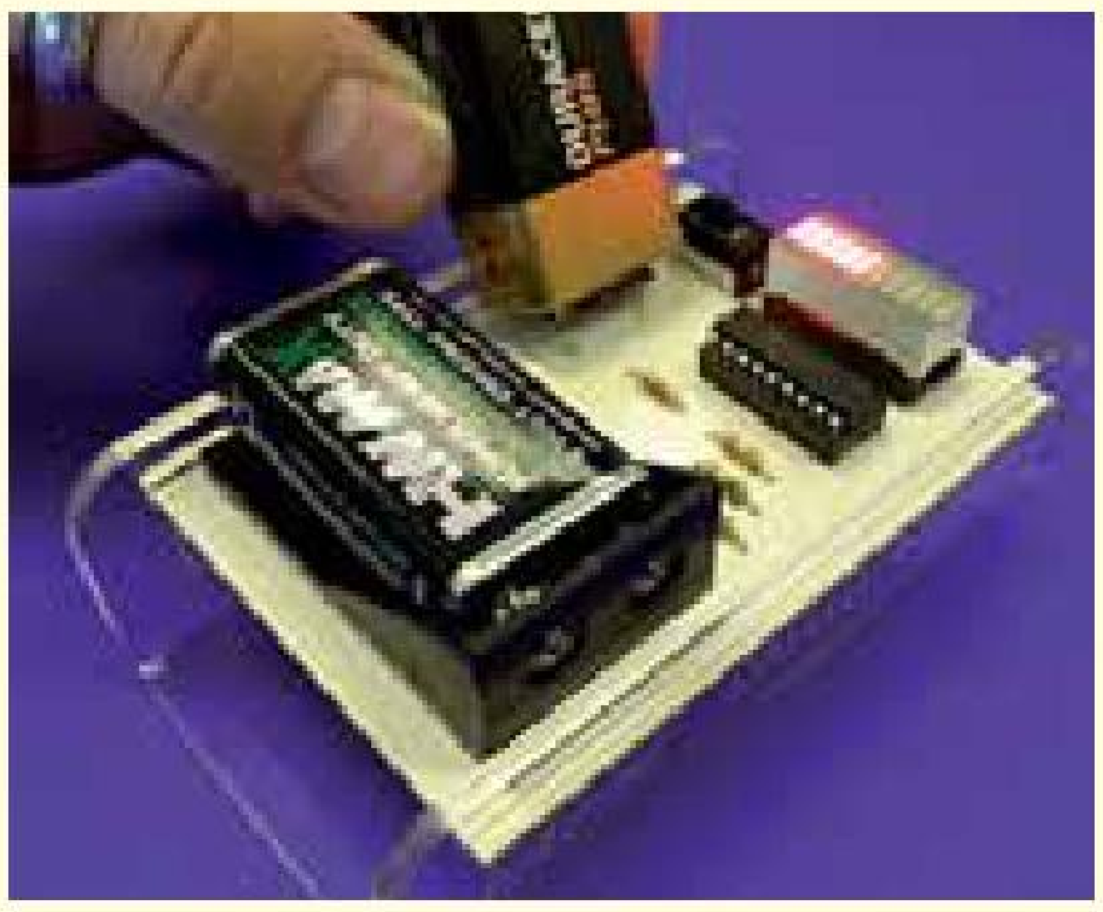
The finished acrylic base



Completed *Battery Voltage Checker*



Testing a new battery

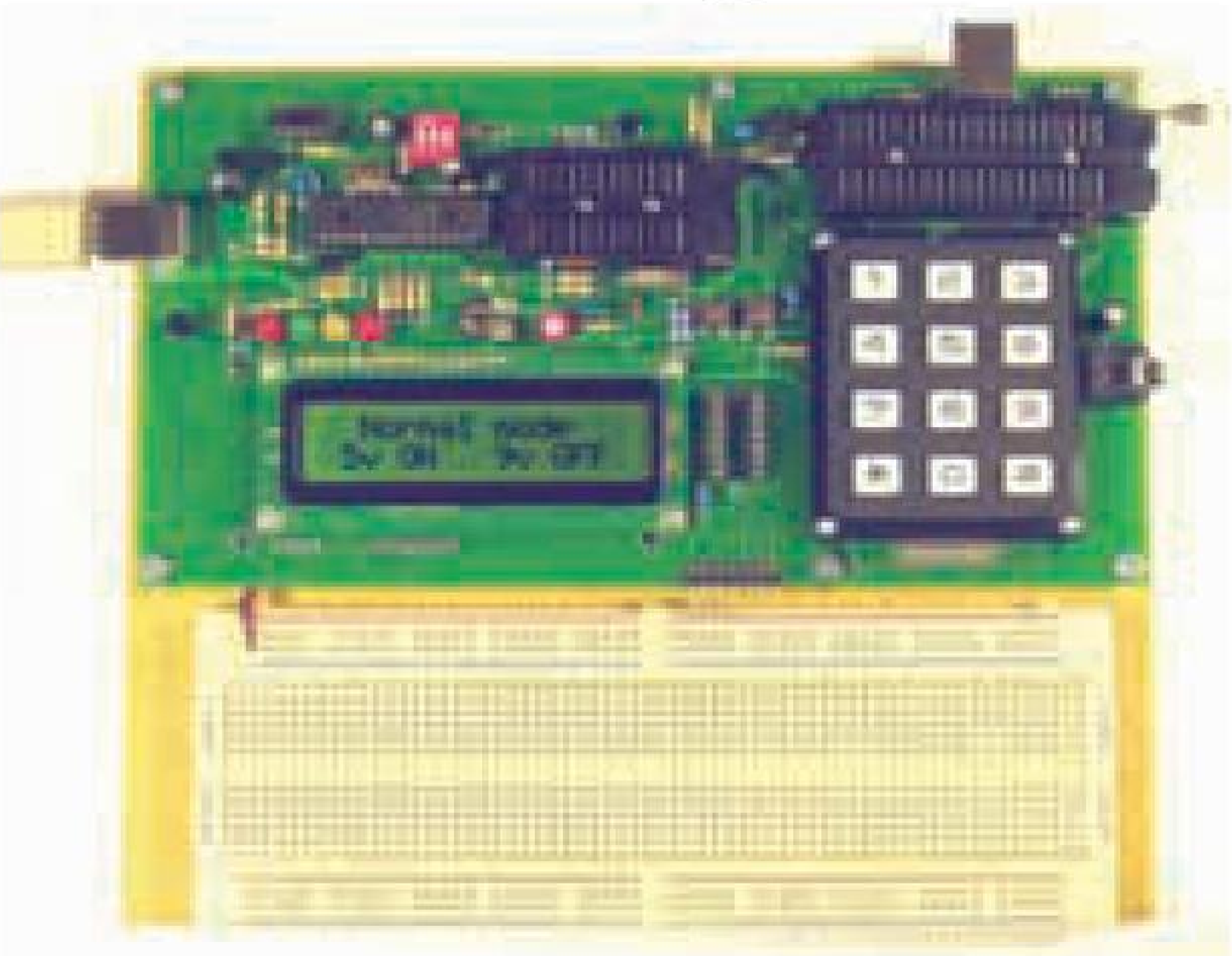


Testing a 'flat' battery

Special thanks to Chichester College *for the use of their facilities when preparing the featured circuits.*

For more info:
www.tooley.co.uk/epe

PIC Training Course



P931 Course £148

The control PIC of our programmer has two modes of operation, its normal programming mode, and a USB to USART mode. Programme your PIC in the usual way then flip the red switches and your PIC can use the control PIC as a serial link to your PC. All designed to make the learning process as straightforward as possible. We have also reduced the component count and lowered the price.

The course follows the same well proven structure. We begin learning about microcontrollers using the incredible value 18 pin PIC16F1827. At the heart of our system are two real books which lie open on your desk while you use your computer to type in the programme and control the hardware. Start with four simple programmes. Run the simulator to see how they work. Test them with real hardware. Follow on with a little theory.....

Our PIC training course consists of our PIC programmer, a 318 page book teaching the fundamentals of PIC programming, a 304 page book introducing the C language, and a suite of programmes to run on a PC. Two ZIF sockets allow most 8, 18, 28 and 40 pin PICs to be programmed. The programming is performed at 5 volts then verified at 5 volts and 2 volts or 3 volts.

P931 PIC Training & Development Course comprising.....
USB powered 16F and 18F PIC programmer module
+ Book Experimenting with PIC Microcontrollers
+ Book Experimenting with PIC C 6th Edition
+ PIC assembler and C compiler software on CD
+ PIC16F1827, PIC16F1936 & PIC18F2321 test PICs
+ USB cable. £148.00
(Postage & insurance UK £10, Europe £20, Rest of world £30)

Experimenting with PIC Microcontrollers

This book introduces PIC programming by jumping straight in with four easy experiments. The first is explained over seven pages assuming no starting knowledge of PICs. Then having gained some experience we study the basic principles of PIC programming, learn about the 8 bit timer, how to drive the liquid crystal display, create a real time clock, experiment with the watchdog timer, sleep mode, beeps and music, including a rendition of Beethoven's *Fur Elise*. Then there are two projects to work through, using a PIC as a sinewave generator, and monitoring the power taken by domestic appliances. Then we adapt the experiments to use the PIC18F2321. In the space of 24 experiments, two projects and 56 exercises we work through from absolute beginner to experienced engineer level using the very latest PICs.

Experimenting with PIC C

The second book starts with an easy to understand explanation of how to write simple PIC programmes in C. Then we begin with four easy experiments to learn about loops. We use the 8/16 bit timers, write text and variables to the LCD, use the keypad, produce a siren sound, a freezer thaw warning device, measure temperatures, drive white LEDs, control motors, switch mains voltages, and experiment with serial communication.

Web site:- www.brunningsoftware.co.uk

Serial Coms Extension £31

This third stage of our PIC training course starts with simple experiments using 18F PICs. We use the PIC to flash LEDs and to write text to the LCD. Then we begin our study of PC programming by using Visual C# to create simple self contained PC programmes. When we have a basic understanding of PC programming we experiment with simple PC to PIC serial communication. We use the PC to control how the PIC lights the LEDs then send text messages both ways. We use Visual C# to experiment with using the PC to display sinewaves from simple mathematics. Then we expand our PC and PIC programmes gradually until a full digital storage oscilloscope is created. For all these experiments we use the programmer as our test bed. When we need the serial link to the PC we flip the red switches to put the control PIC into its USB to USART mode.

In the second part of *Experimenting with Serial Communications* 4th Edition we repeat some of the serial experiments but this time we use a PIC18F2450 with its own USB port which we connect directly to a USB port of your PC. We follow this with essential background study then work through a complete project to use a PIC to measure temperatures, send the raw data to the PC, and use the PC to calculate and display the temperature.

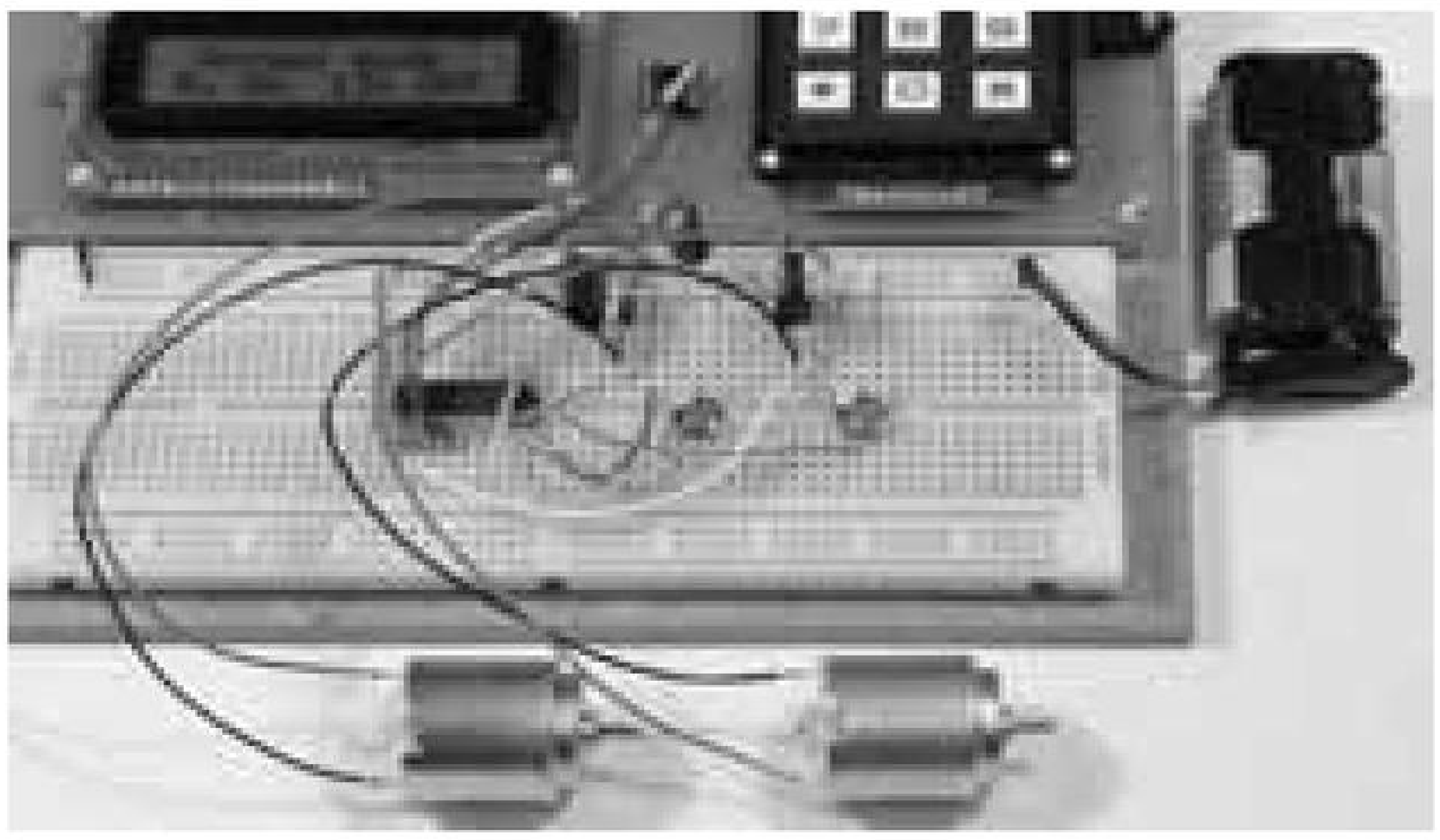
290 page book + PIC18F245 test PIC + USB lead.... £31

P942 Course £168

This has the same books and features as the P931 course. The P942 programmer/development module can be powered from a separate PSU (programming verified at 5.5 volts, 5 volts and 2 or 3 volts) or powered from USB (programming verified at 5 volts and 2 volts or 3 volts). The P942 can programme 3.3 volt as well as 5 volt 16F and 18F PICs, and has an RS232 port as well as the USB port for experimental use. See website for details.

Ordering Information

Our P931 & P942 programmers connect directly to any USB port on your PC. All software referred to operates correctly within Windows XP, NT, 2000, Vista, 7 etc.Telephone for a chat to help make your choice then go to our website to place your order (Google Checkout or PayPal), or send cheque/PO, or request bank details for direct transfer. All prices include VAT if applicable



White LED and Motors

Our PIC training system uses a very practical approach. Towards the end of the PIC C book circuits need to be built on the plugboard. The 5 volt supply which is already wired to the plugboard has a current limit setting which ensures that even the most severe wiring errors will not be a fire hazard and are very unlikely to damage PICs or other ICs.

We use a PIC16F1827 as a freezer thaw monitor, as a step up switching regulator to drive 3 ultra bright white LEDs, and to control the speed of a DC motor with maximum torque still available. A kit of parts can be purchased (£31) to build the circuits using the white LEDs and the two motors. See our web site for details.

Mail order address:

Brunning Software

138 The Street, Little Clacton, Clacton-on-sea,
Essex, CO16 9LS. Tel 01255 862308

PIC n' Mix

Mike Hibbett

Our periodic column for PIC programming enlightenment

Generating pixel data for the VGA LCD Monitor

We continue this month with our attempt to produce a video library for the chipKIT Uno32, capable of driving a standard VGA LCD monitor. So far, we have been able to create the horizontal and vertical sync signals required to lock a monitor onto a display resolution of 800 × 600 pixels. The question now is: can we generate the actual pixel data, at a fast enough rate, in step with the sync signals? This month we finally find out exactly what the Uno32 is capable of.

We've already established that we cannot write the pixel data using software, because a new pixel must be written every 25nS, and a single instruction takes about that length of time. Plus, the data must be written at a very specific time after the horizontal pulse, or the screen flicker will be annoying.

Clearly, we need the support of a hardware peripheral. So which ones do we have left available? The usual candidates such as Output Compare, Parallel Master and Slave Port do not provide the flexibility to feed individual pixel data. The only peripheral left to us is the SPI module.

SPI module

First, a bit of background to the SPI module. It's designed to exchange data between devices such as flash memory chips or LCDs in a serial fashion, similar to a UART. It differs from a UART in that it provides a clock signal in addition to a transmit and receive line, removing the need for precise agreement between the two communicating devices as to the speed at which data is transferred.

The SPI module can be configured in two modes; master, where the processor is the source of the clock signal and controlling the exchange of data, and slave mode, where the processor receives a clock signal from another device, and responds to data sent to it.

When configured in master mode, the SPI module will transmit data, one bit at a time, at a fixed rate determined by a baud-rate generator register setting. The SPI module also sends a clock signal (that the remote device would use to clock the data in with), but we can safely ignore this signal in our application. A quick check of the baud rate register in the datasheet confirms that with the crystal fitted to the Uno32 we can run at a rate of exactly 40MHz – perfectly matching our pixel rate.

Unfortunately, with only two SPI modules available and insufficient memory or processing time available, we will have to stick to using a single SPI module. And that means that our pixel data will be displayed in monochrome (ie, a single colour.) On the plus side, by fiddling with resistor values, you can choose any colour. For simplicity, ease on the eye and a nod to historic computer terminals we went with green.

The SPI peripheral module has some helpful features that we can make use of in this application. We can set the module to transmit 32-bits at a time (ie, 32 pixels) and 'queue up' another 32-bit word for transmission while the first is being transmitted – this way, we have some processing time available to do other things.

Crucially, when words are queued to the SPI module there will be no time gaps between words being transmitted – thus, we can send a stream of 25 words (800 pixels) without 'jitter' appearing on the display. It's a reasonably efficient way of generating the data – other PIC processors have additional features (such as direct memory access controllers) that can make this process even more efficient, but the SPI module by itself will suffice for our needs.

It's almost time to show the final circuit, but before we do there is one detail still missing – how do we accurately time the sending of pixel data relative to the horizontal sync signal?

Generating pixels

Digging through the reference manual on the SPI module for the PIC32 (document number DS61106F from Microchip) revealed an interesting Microchip-specific extension to the SPI interface standard – the Slave Select feature. Not to be confused with the master and slave modes of SPI data transfer, this feature allows the transmission of data from a master device to be 'held off' until a specific input pin (called a Slave Select input, SS1 or SS2) changes state.

So how can we use this? By cunningly tying the horizontal sync output pin *back* onto one of the Slave Select input pins. This way, data transfer will not start until the horizontal sync pin triggers. As the two features are linked by hardware alone (the Slave Select input does not generate an interrupt, it simply starts data transfer immediately) there are no time delays and the pixel data should appear without any jitter. This technique of wiring one pin back to another simply to link two or more peripheral modules together is often used within microprocessor systems, and is an approach that is well worth remembering.

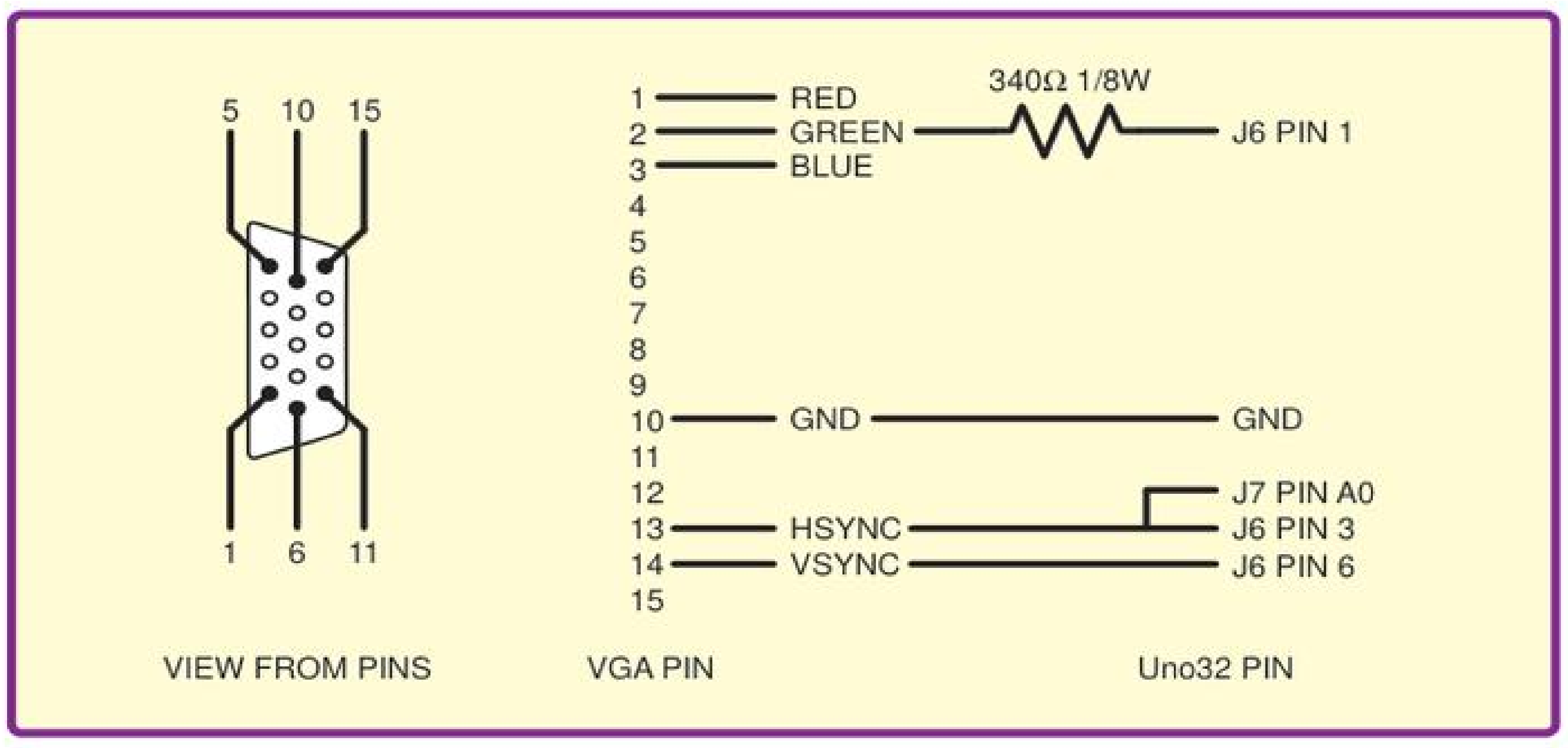


Fig.1. VGA interface circuit

The circuit

So this brings us to the final circuit diagram, shown in Fig.1. Here you can see the horizontal sync signal coming out of the processor on J6 pin 3 and going back into the processor on J7 pin A0, which is one of the Slave Select inputs. The horizontal sync signal does, of course, continue on out to the VGA connector.

The SPI output signal appears on J6 pin 1 and goes (via a 340Ω resistor) to the connector. This resistor, coupled with the monitors 75Ω input impedance, will give a sufficient voltage drop for a bright green pixel to appear on screen at the appropriate pixel location.

Fig.2 shows how we have wired this up – no PCB required, this is a simple enough circuit to leave as wire connections on the end of the VGA cable. The resistor is placed in line, and covered with heatshrink tubing for protection.

For the more adventurous, three 470Ω trimmer resistors could be connected instead, and wired to the three colour signals on the VGA cable to allow the selection of any colour. The net result will be the same though – a single colour for all data displayed.

Displaying pixels

So, with the principle of *how* we can generate pixel data in perfect synchronisation with the horizontal sync pulse behind us, it's time to write some code to test it out. Within the horizontal interrupt we count each line, and start generating pixel data after the initial 'blanking' lines, as defined by the VGA standard.

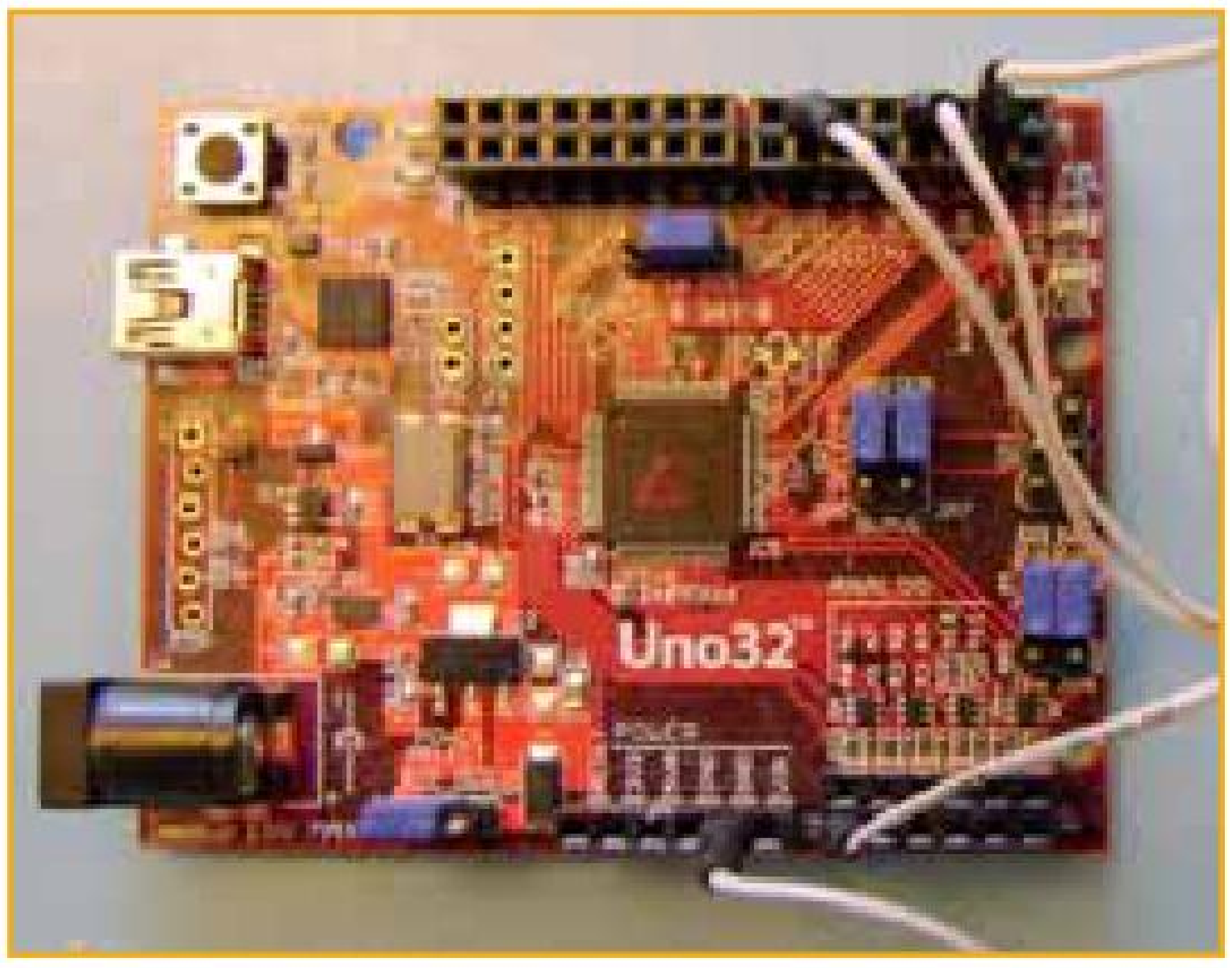


Fig.2. Example wiring

The approach we take for displaying text is to create a two dimensional array of characters representing the contents of the display, and a font table representing a particularly sized font (six pixels wide by eight pixels deep) for each of the possible ASCII characters. The video display driver will then read a line of text and for each of the eight rows of pixels look up the co-responding pixel data, forming a line of pixels to display. When a horizontal sync interrupt occurs, this line of pixels will be fed to the SPI peripheral. While that line is being transmitted by the SPI peripheral, the next line of pixels can be prepared in a second pixel line buffer. The interrupts then 'ping-pong' between the two pixel line buffers.

Not all of the display line is actually visible; at a resolution of 800 × 600, each line is actually 1056 pixels wide, and those unused pixels must be drawn in the 'off' state or the display will not synchronise to our video signal. To achieve this in the simplest manner we add some unused 'characters' to our screen buffer. While not particularly elegant (we loose some of the visible area on screen) it is efficient, and efficiency is important – we need to preserve as much processing power as possible for whatever our main application is doing.

This is a short piece of code that hides the complexity of its design (it took several evenings of experimentation to arrive at) but as it is not the main focus of this article we won't go into the details. We will pick up on this next month.

Lowering the resolution

Initial experiments with this circuit and software revealed a problem that we suspected from the beginning – without the support of a DMA module to automate the transfer of pixel line data from memory to the SPI module, we do not have enough processor time available to create the next line of pixels before the current line has finished being displayed. This resulted in some quite bizarre screen effects that were amusing but completely unreadable.

Careful optimisation of the software did not help enough; we had to go to a radical solution – reducing the displayed resolution.

By halving the SPI data rate and pixel resolution, but keeping the physical resolution the same, we halved the number of text characters that had to be processed for each display line, saving a significant amount of processing time. Now the display worked perfectly, and filling the text buffer with some sample data, the output shown in Fig.3 was created.

So far all of this work has been prototyping and experimentation. The crude software source code – crude but working – can be found on the magazine website in the usual download location.

Now that we have a working system, it's time to consider how to turn this code into a library module. There are a number of factors to consider, and we will resolve these next time when we complete the task, make an easy-to-use library, and provide a more detailed explanation of how the video software operates.

ChipKit MAX32 Max

This series of articles has been based on the low-cost Uno32 platform. Will this code drive a Max32 platform? It should be able to, but we haven't tested it. Can the Max32 hardware do a better job? Yes, as it has a direct memory access module (DMA) that can take care of transferring the data to the SPI peripheral – which would enable the full 800 × 600 pixel resolution display, and allow for some limited graphics handling.

Would it be worth bothering? Probably not, as there are now better hardware platforms available for a similar price to the Max32 that are capable of displaying high definition video natively. We are, of course, referring to the Raspberry Pi. Circuits like this do, however, have their place – they are simple to use, (developing for a Linux platform such as the Pi will require a steep learning curve) and they draw less power.

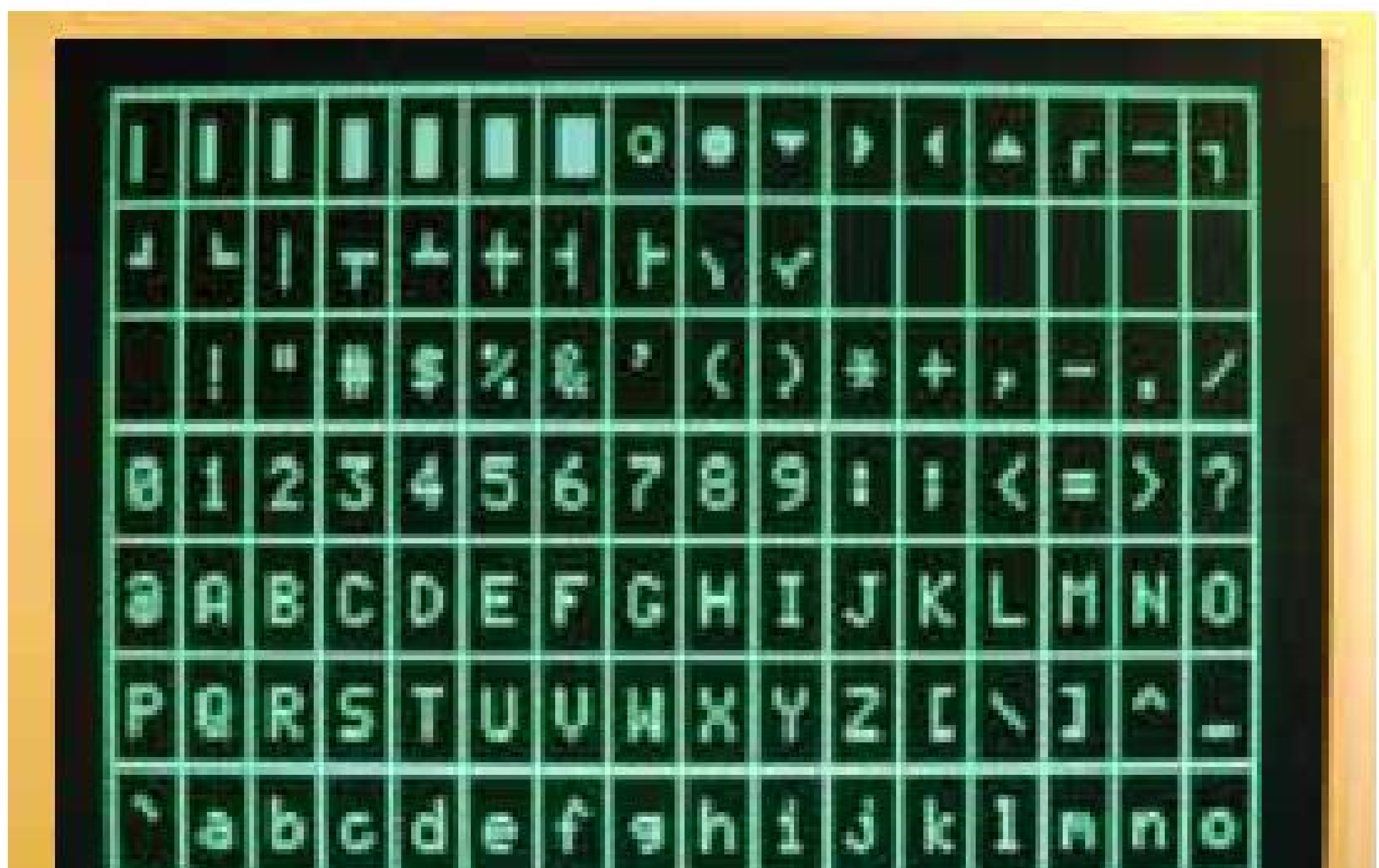

! " # $ % & ' ( ) * + , - . /
0 1 2 3 4 5 6 7 8 9 : ; < = > ?
@ A B C D E F G H I J K L M N O
P Q R S T U V W X Y Z [\ ] ^ _
` a b c d e f g h i j k l m n o
p q r s t u v w x y z { | } → ←

Fig.3. Sample output – the font set

Compact Control Design

New radio products

Remote switch

Add remote control to any kind of switch. 1,2,3,4 gang versions available.
Receiver controls power to any appliance up to 5 Amp.
Add lighting without messy wiring.
Outside lights, security lights.
Pond pump remote control.
Remote control sockets.

Smart controller

Clock and 7 day timer.
Temperature and light sensors. Use any combination to control many household functions. Ideal for-

•Smart central heating.
•Security systems.
•Indoor/outdoor lighting.
•Garden features (pond pumps etc)
Can control many things from 1 controller.

Remote logger

Boxed or PCB version. 1 input.
Measures-
Switch (remote control or metering)
Pulse (metering applications)
Voltage, Current or Temperature.
Boxed version has 1/2 AA lithium cell with 10 years expected life.

USB radio

Radio transceiver in USB dongle.
Emulates CDC device, appears as a serial port.
Implements simple data link, point to point, networks, groups etc. Data logger and management software available.

Simple radio

Includes UART port, send data into one device and it comes out of the others, no config needed. Also supports-
Point to point, groups, networks etc.
Low duty cycle mode for low power apps.
Includes PIC micro.

www.compactcontrol.co.uk
Phone: +44 1260 281694
Fax: +44 1260 501196
sales@compactcontrol.co.uk

EPE EXCLUSIVE

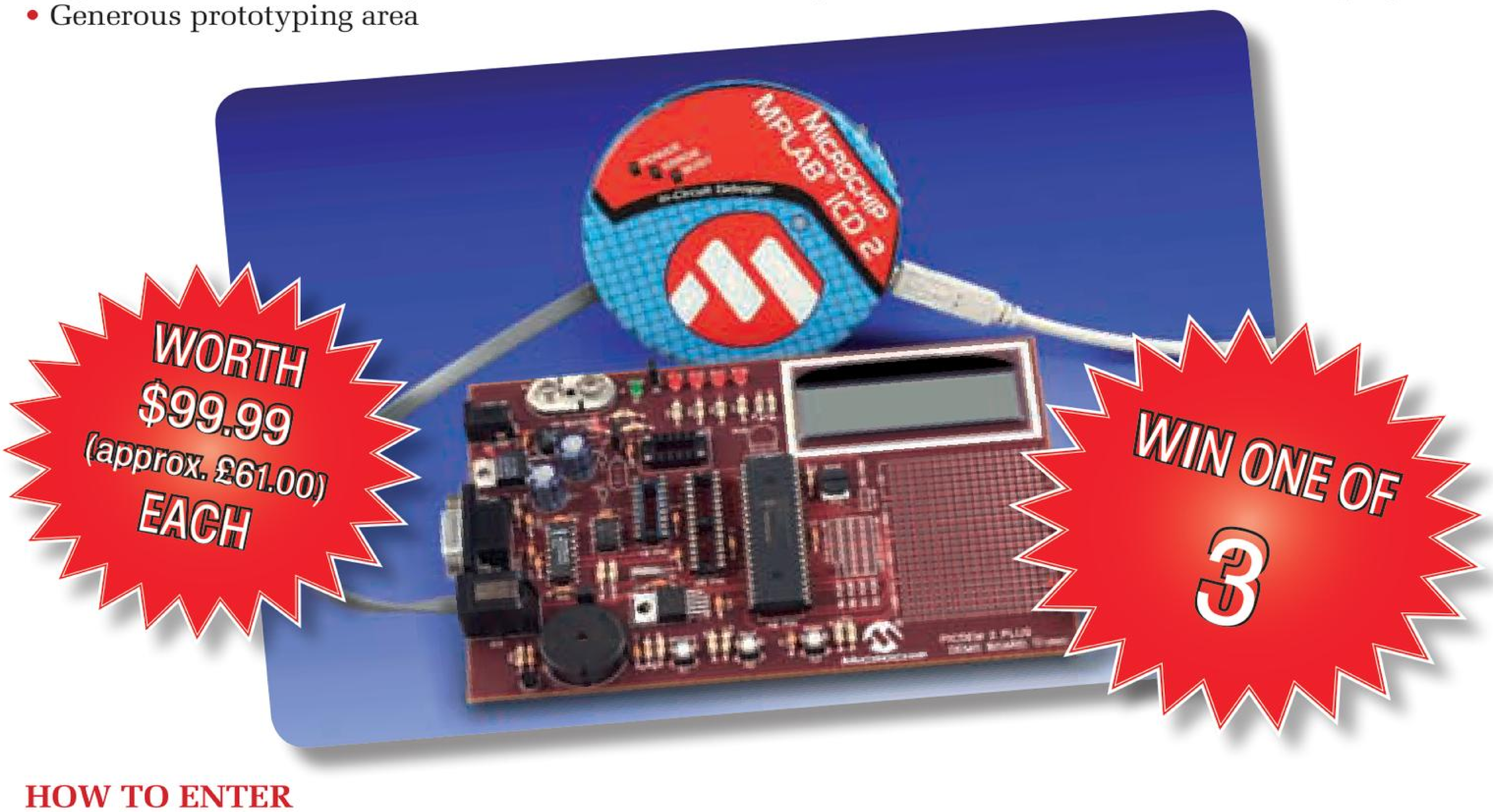
Win one of three Microchip PICDEM 2 PLUS Boards

EVERYDAY PRACTICAL ELECTRONICS is offering you the chance to win, one of three Microchip PICDEM 2 PLUS Boards. This board demonstrates the capabilities of Microchip's 8-bit microcontrollers, specifically, 18-, 28- and 40-pin PIC16Fxxx, PIC16F1xxx, and PIC18 devices.

It can be used as a standalone demonstration board, with a programmed part. Alternatively, it can be used with an in-circuit emulator (for example, MPLAB Real ICE) or with an in-circuit programmer/debugger (such as MPLAB ICD 3 or PICkit 3). Sample programs are provided to demonstrate the unique features of the supported devices.

KEY FEATURES

Demonstration program displaying a real-time clock, ambient temperature and much more • A demonstration program loaded on the installed PIC16F1937 (40-pin) MCU • Sample kit with PIC16F1827 (18-pin), PIC16F1936 (28-pin) and PIC18F46K22 (40-pin) MCUs • Source code for all programs • Generous prototyping area



HOW TO ENTER

For your chance to win one of the PICDEM 2 Plus Boards, visit: **http://www.microchip-comps.com/epe-2plus** and enter your details in the online entry form.

CLOSING DATE

The closing date for this offer is 31 July 2012

EPE Online
www.epemag.com

Get your magazine 'instantly' anywhere in the world –
buy and download from the web.

TAKE A LOOK, A FREE ISSUE IS AVAILABLE

A one year subscription (12 issues) costs just

$19.99(US)

Back issues are also available

Coast

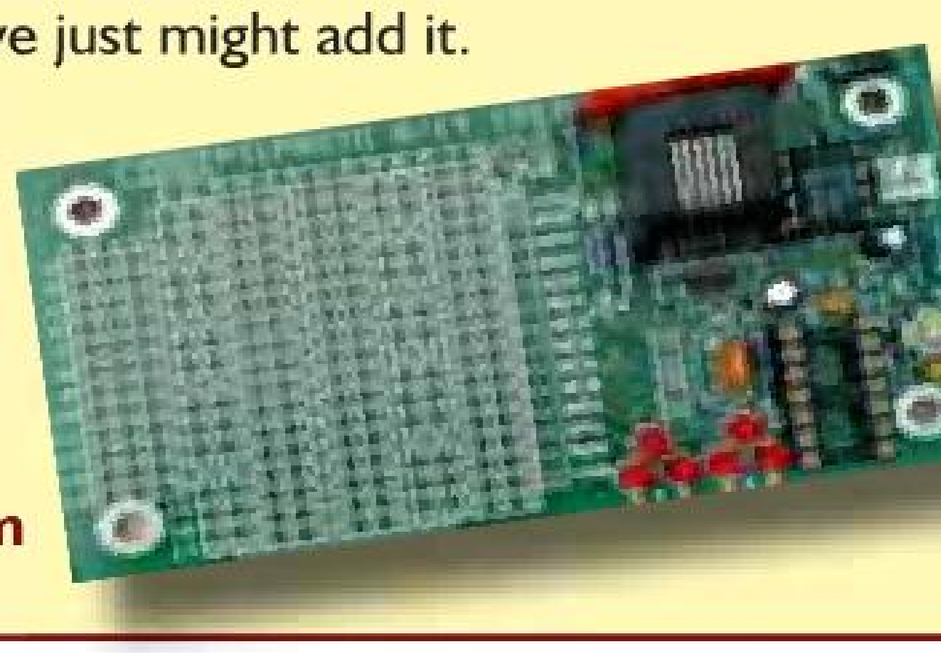
Sorting out your bits and pieces? Check out our E-shop...

...We offer components, modules, kits, Led lighting, musical stuff, Industrial, Contract design, device programming, short-range radio, scientific items …and some really weird things!

And if we don't have what you need... let us know... we just might add it.

COAST ELECTRONICS
8 HOLWORTH CLOSE
BOURNEMOUTH
BH11 8PF
Tel:01202 244309

www.coastelect.com



Laser

Why tolerate when you can automate?

X-10 Home Automation

KAT5 AV transmission and IR control system

Barix Ethernet based MP3, communications and control systems

www.laser.com

Integrators, Installers, Trade and Retail customers welcome

C-Bus Shop
C-Bus and
C-Bus Wireless

www.cbus-shop.com

Laser Business Systems Ltd
Tel: +44 (0) 20 8441 9788
Fax: +44 (0) 20 8449 0430
Email: info@laser.com
16 Garthland Drive, EN5 3BB

TO ADVERTISE IN *EVERYDAY PRACTICAL ELECTRONICS*
PLEASE CONTACT
Stewart Kearn on
01202 880299

www.matrixmultimedia.com

MATRIX

industrial control
and data-logging modules

ZIGBEE SPI CAN GSM USB RS232 GPS BLUETOOTH RS485 TCP/IP SD/FAT16

MIAC

- based on PIC technology
- full graphical programming language
- supports wired and wireless communication protocols
- compatible with industrial sensors, lab sensors and add-ons

CIRCUIT SURGERY

REGULAR CLINIC

BY IAN BELL

Output buffers

LAST month, we started to address a set of questions about output buffer amplifiers posted on *EPE's Chat Zone* by ***atferrari***.

I am about to build an output stage for a sine generator. I ran across several circuits of AB class amplifiers, but in spite of lot of reading, I still have many basic doubts. My questions are:

1) A buffer output is expected to have gain by itself? In other words, what defines the gain in a push-pull configuration?

2) Several function generators seem to set their output impedance just by using a series resistor of 50Ω/75Ω/600Ω at the output. Is that all that is needed?

3) Instead of building an AB stage, the LH0033 (or similar buffer), would be a better (if expensive) solution?

4) When reading about AB amps, it seems that those specifically for audio and those used as an output stage of signal generators share different necessities. Besides the obvious low impedance loads in audio, is there anything else that makes them so different?

5) Walter Jung in his IC Op-amp Cookbook *describes a circuit that has an output impedance of 10Ω [this has a class AB amplifier, and an op amp in a feedback loop]. What determines that value? How could I change it, if possible?*

6) I read somewhere in a forum that diodes [used for biasing] are old use; that a V_{be} multiplier should be used instead. Can anyone elaborate?

Gracias for any help to understand this a little more.

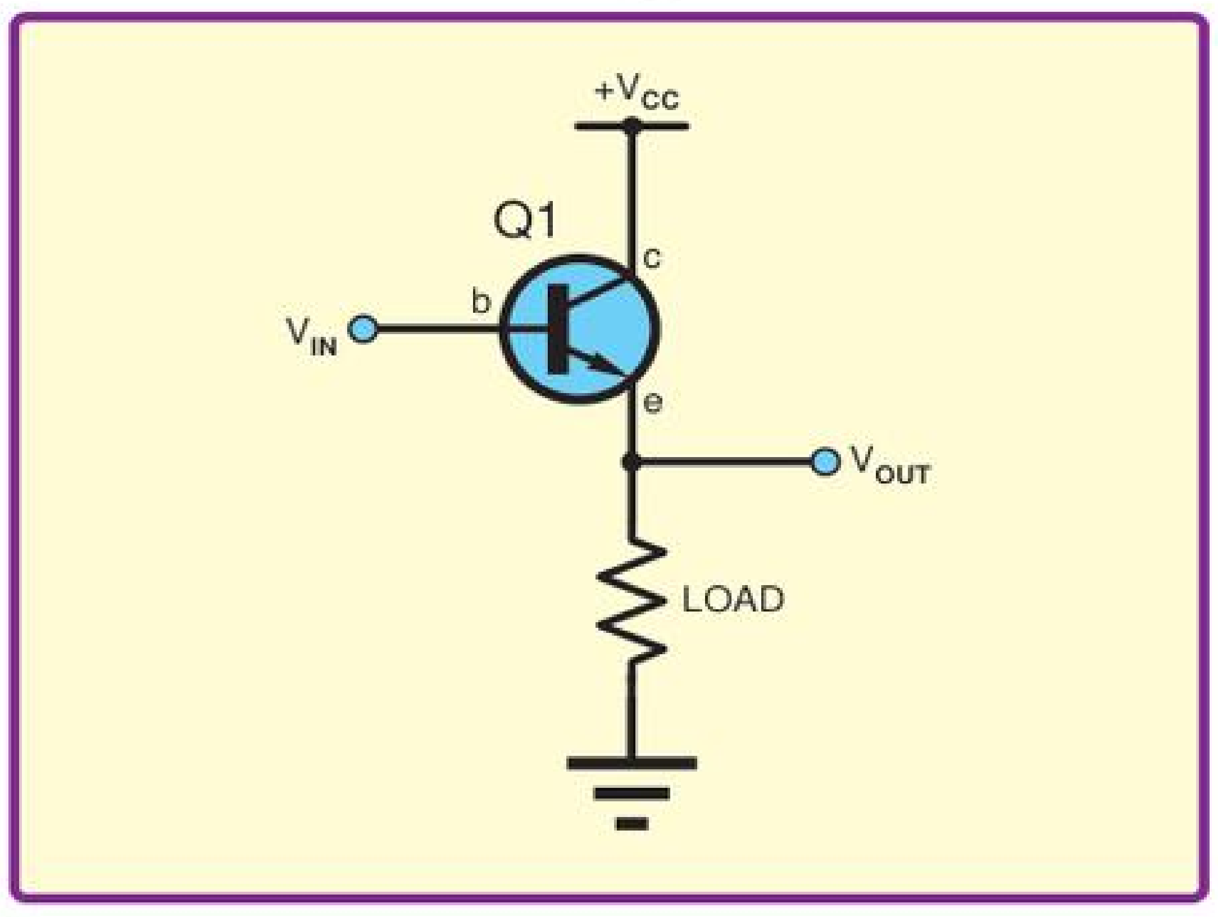


Fig.1. Emitter follower

Output buffer

An output buffer is a circuit which sits between a signal processing or generating, circuit and the load, and provides the characteristics necessary to drive the load correctly. Last month, in answer to the first question, we saw that buffers typically have unity voltage gain; but they deliver significant power gain because they can provide more output current, than the preceding circuit stage.

In audio systems, the term power amplifier may be used for circuits which are similar to those called output buffers in other contexts. The term 'power amplifier' conjures images of circuits which deliver many watts of power. This does not have to be the case – it is the fact that power gain is provided rather than the amount of power available that matters.

In some cases, the gain accuracy of a buffer is critical, so that it does not shift the voltage levels it is buffering. This is relevant to question 4, in that buffer gain accuracy may be critical in, for example, a laboratory signal generator and much less so in, say, a headphone amplifier.

Output buffers typically have low output impedance, and output

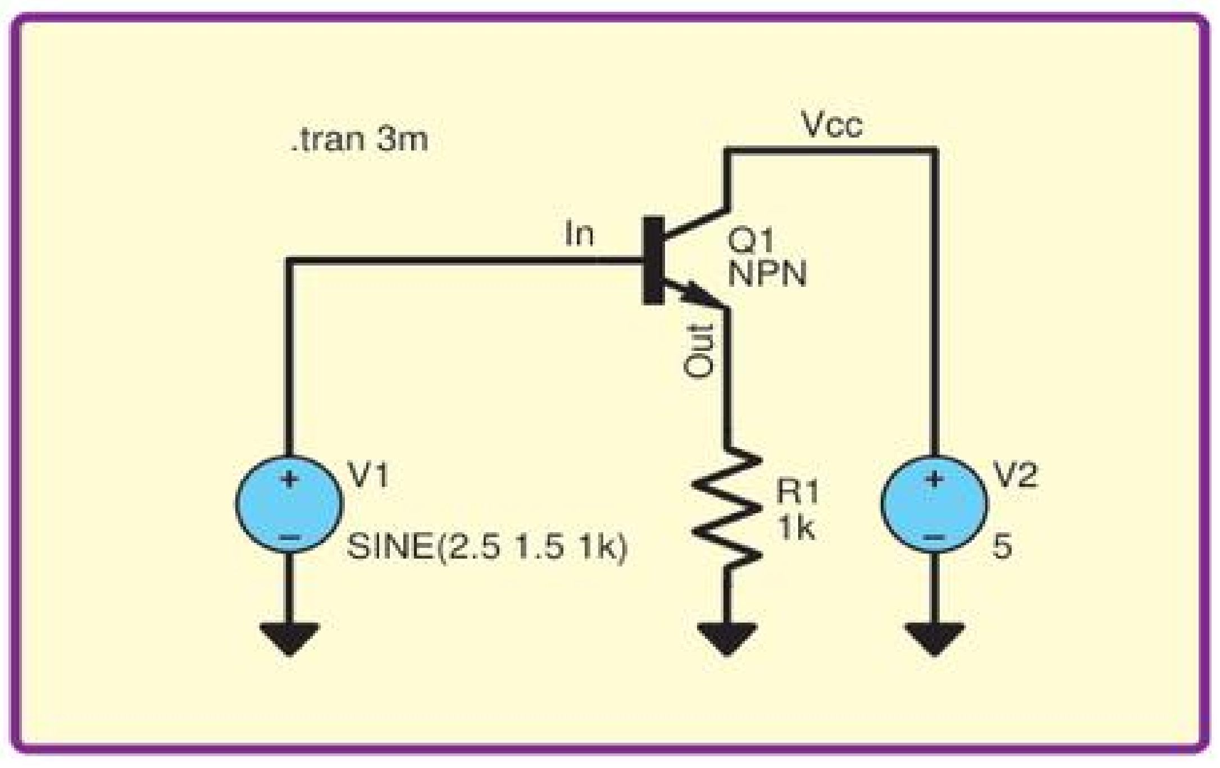


Fig.3. LTSpice schematic used to model Fig.2. This uses a default transistor model, not one of a specific real device

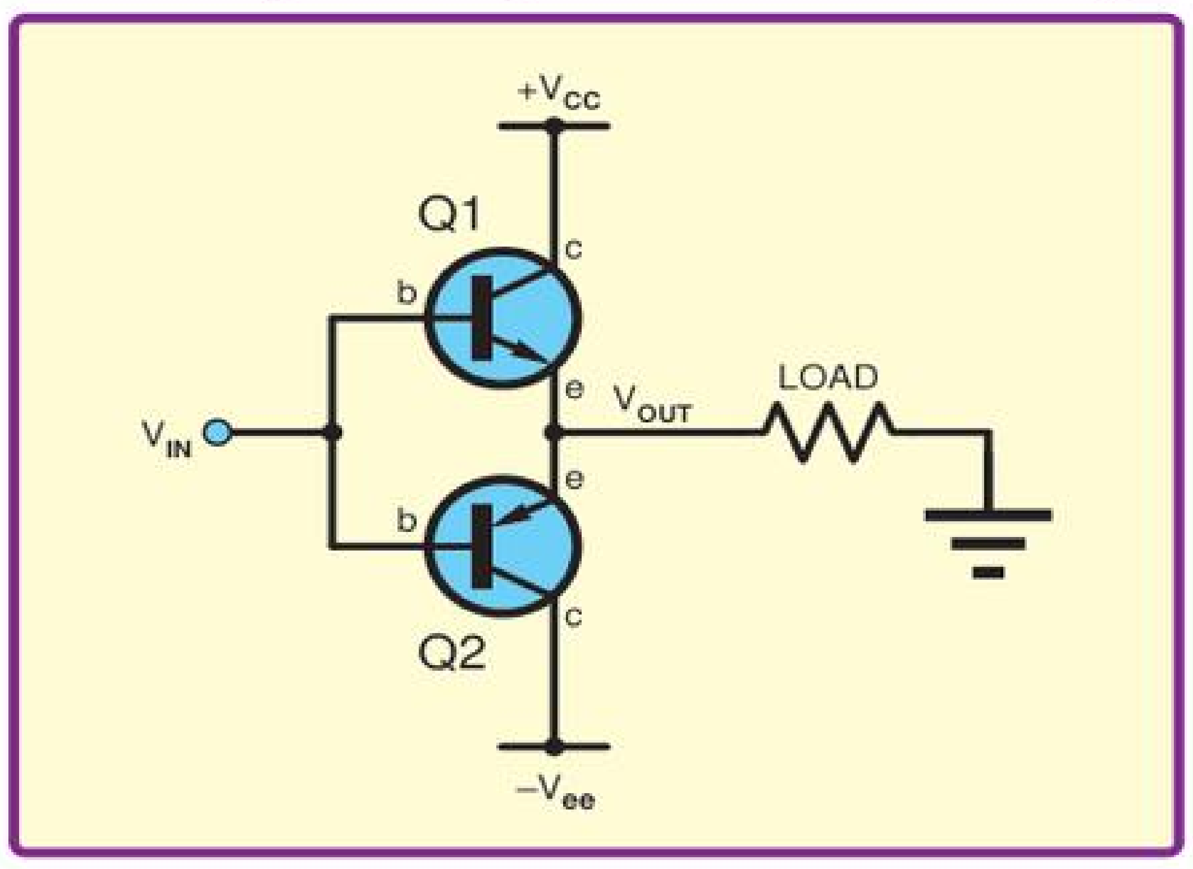


Fig.4. Basic push-pull amplifier

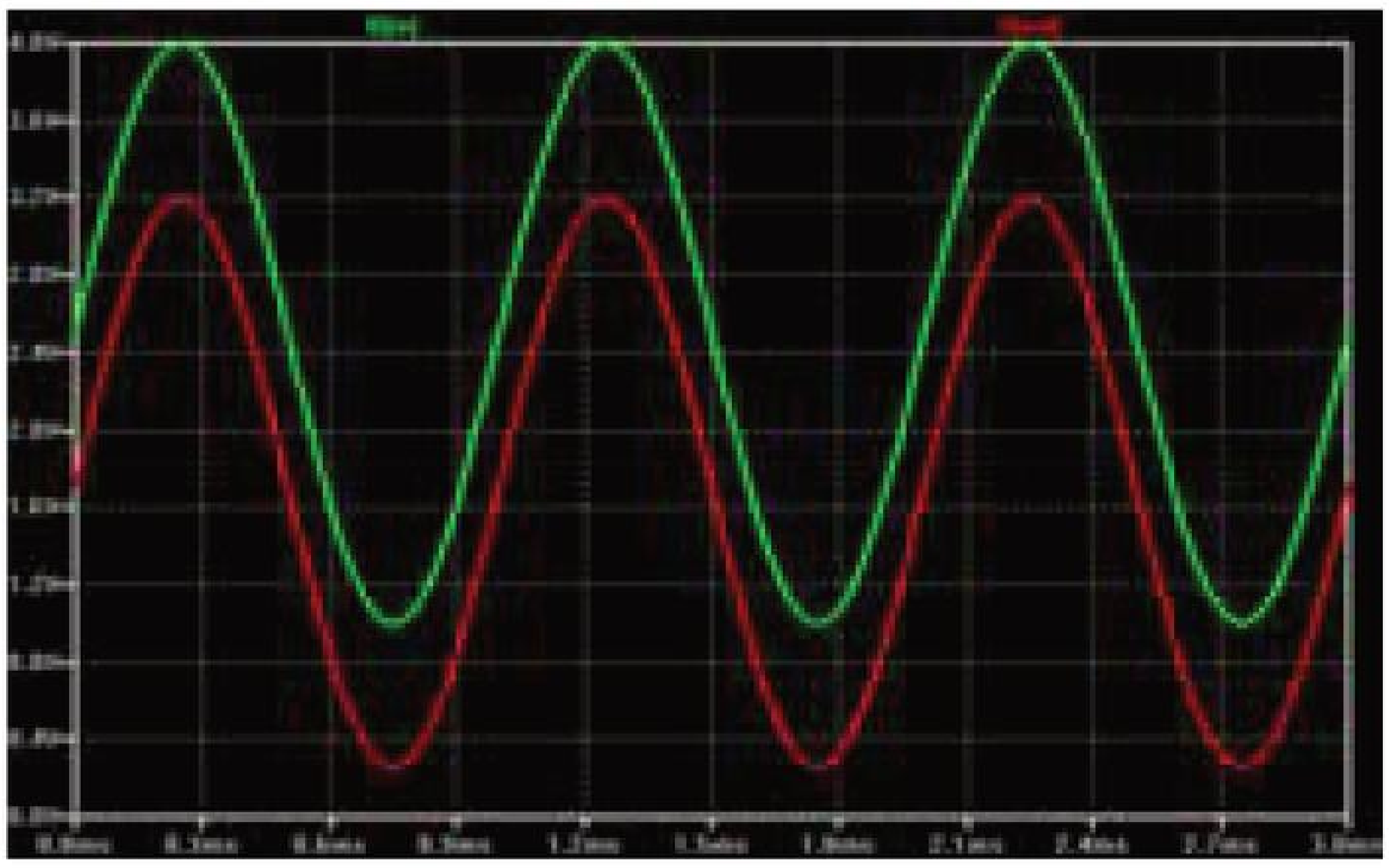


Fig.2. Signals in the emitter-follower circuit (LTSpice simulation)

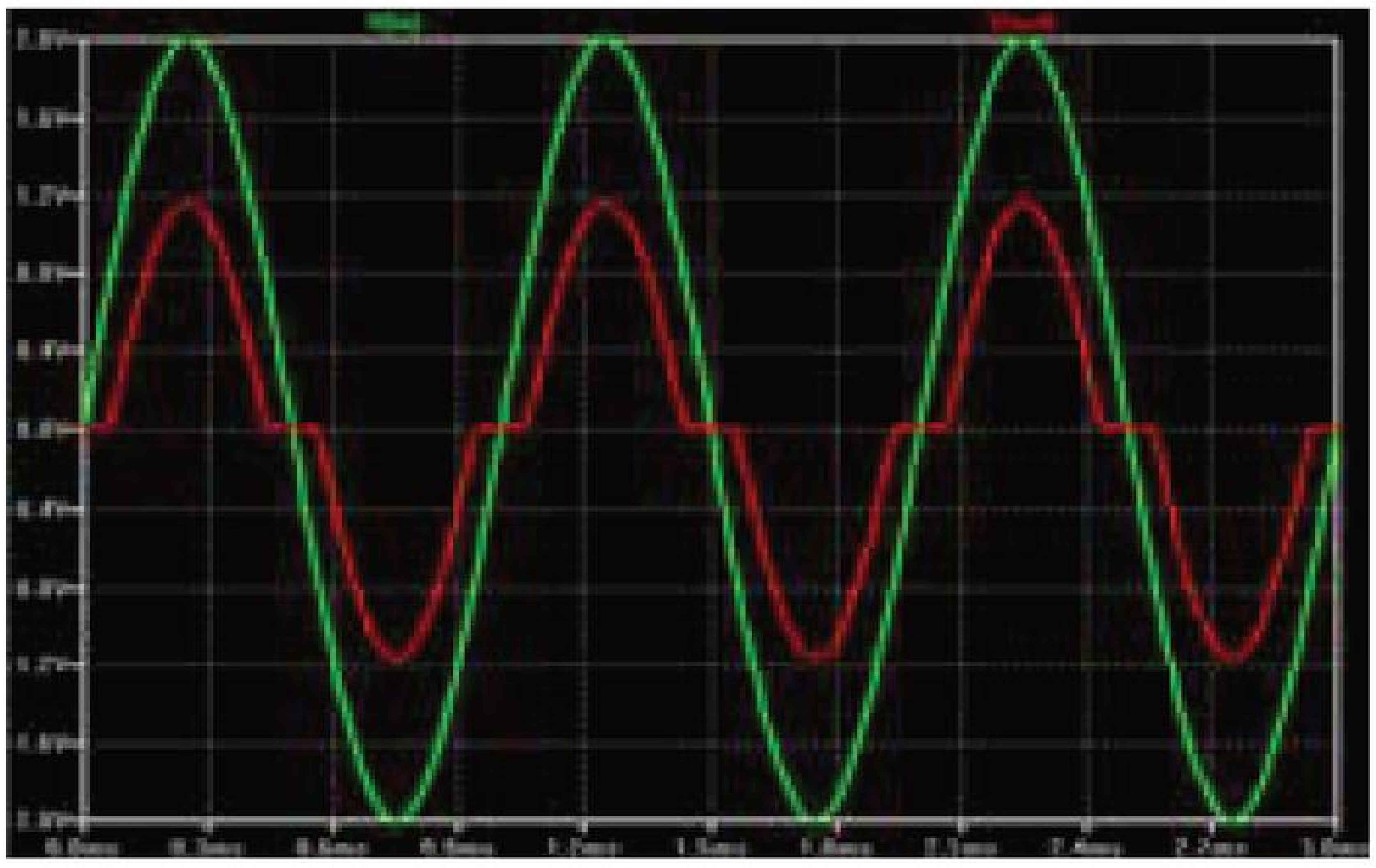


Fig.5. Signals in the basic push-pull amplifier showing sinewave with crossover-distortion (LTSpice simulation)

buffers can be thought of as providing impedance transformation from the relatively high impedance of the signal source being buffered to their own low impedance output. Last month, we discussed output impedance in general, including Thévenin's theorem as the basis of the idea of output impedance.

When the output drives the load via a short length of wire, usually all that is required is a low output impedance. However, for longer cables, the interconnection behaves as a transmission line and the output impedance must be matched. What constitutes a long or short interconnection depends on frequency, the critical length decreasing as frequency increases. Last month, we showed that resistors can be added to a buffer's output to provide matching, as discussed in question 2. We also saw that resistors may also be added to a buffer's output for another reason: to increase stability when driving capacitive loads. This may be necessary when the buffer is included in a feedback loop, such as the circuit mentioned in question 5.

In summary, from the preceding discussion, such a circuit must be capable of supplying sufficient current to the load, have low output impedance and provide power gain. It does not have to provide voltage gain, as this is provided by earlier stages (where applicable). This month, we will look at some of the basic circuit structures used in buffers and power amplifiers. These will not be full practical designs, but will illustrate the basic principles behind them.

Emitter follower

As we noted last month, the term voltage follower is also used for unity-gain buffer circuits. The term is perhaps most well-known in the context of the emitter-follower circuit (Fig.1), which is a very basic buffer amplifier. The emitter follower has a voltage gain of just less than unity, high input resistance and low output resistance. It can deliver a relatively high-current version of a 'weak' voltage signal.

The circuit is called an emitter follower because the *signal* voltage at the emitter (e), which is where the load is connected, 'follows' (is the same as) the voltage at the base (b). The absolute voltage at the emitter is one V_{BE} drop (typically around 0.7V) lower than the base voltage, but this is a shift in DC level, not a change in signal amplitude.

The signals in the emitter follower are illustrated in Fig.2, which was obtained using LTSpice simulation (**www.linear.com/designtools/software**) with idealised (default model) transistors. The schematic shown in Fig.3 was used in LTSpice. Unlike Fig.1, this schematic must explicitly define the supply voltages and input signal source. The unity gain (both have signals the same amplitude) and DC shift of the output (about 0.8V in this case) are visible on the plot. The input signal (V_{IN}, 1.5V, 1kHz sinewave, green trace) is biased with a DC level of 2.5V (half the supply) to prevent the signal from getting low enough to switch off the transistor. The DC level at the output leads to inefficient operation – power is consumed even when no signal is present.

The circuit in Fig.1 has the right kind of properties for an output buffer stage, but it is not suitable if the output signal goes both positive and negative with respect to ground (as is often the case). The transistor in the circuit in Fig.1 would turn off with negative input voltages, so we would only amplify half the signal. To overcome this, two emitter followers can be used in what is known as a 'push-pull' amplifier (Fig.4).

This type of circuit is also referred to as a class B amplifier, because each output transistor is biased in a switched-off condition with no signal present and conducts for only *one half* of the waveform cycle. Transistors in class A amplifiers conduct for the *whole* cycle, for example as shown in Fig.2 for the circuit in Fig.1 and Fig.3. In class C amplifiers, the transistor conducts for less than half the cycle. The class of operation depends on both the circuit structure and bias conditions. For example, the circuit in Fig.3 could be operated in class B by using a lower bias voltage instead of 2.5V.

Crossover distortion

The basic push-pull output stage suffers from a problem called crossover distortion. Only one transistor can be on at any time, that is, if $V_{IN} > V_{BE}$ then Q1 is conducting, and if $V_{IN} < -V_{BE}$ then Q2 is conducting. But this means that for small inputs, neither transistor is on, if $-V_{BE} < V_{IN} < V_{BE}$ then Q1 and Q2 are both off. So signals, or parts of signals, in this range are not amplified, leading to distortion of the output. Distortion is high in class B amplifiers, but they are more efficient than class A. Class C amplifiers have even higher distortion.

Fig.5 shows the effect of a sinewave input to a basic push-pull amplifier (V_{IN}, green trace, 2V peak-to-peak) and the resulting distorted output (V_{OUT}, red trace). Again, this waveform was obtained using LTSpice with default transistor models, as shown in Fig.6. Although this simulation does not use real devices, it is sufficient to demonstrate basic operating principles. The distortion means that this circuit is often not suitable for many applications (eg, audio) it may be usable where the distortion does not matter, for example in a basic motor control circuit.

To overcome crossover-distortion, the output transistors are biased so that with no signal present they are both just on the point of conduction. We then have: when $V_{IN} = 0$ both transistors are just conducting, when $V_{IN} > 0$ Q_1 conducts and Q_2 is off, and when $V_{IN} < 0$ Q_2 conducts and Q_1 is off. This can be achieved using two diodes, or two diode-connected transistors to provide the 2 × V_{BE}

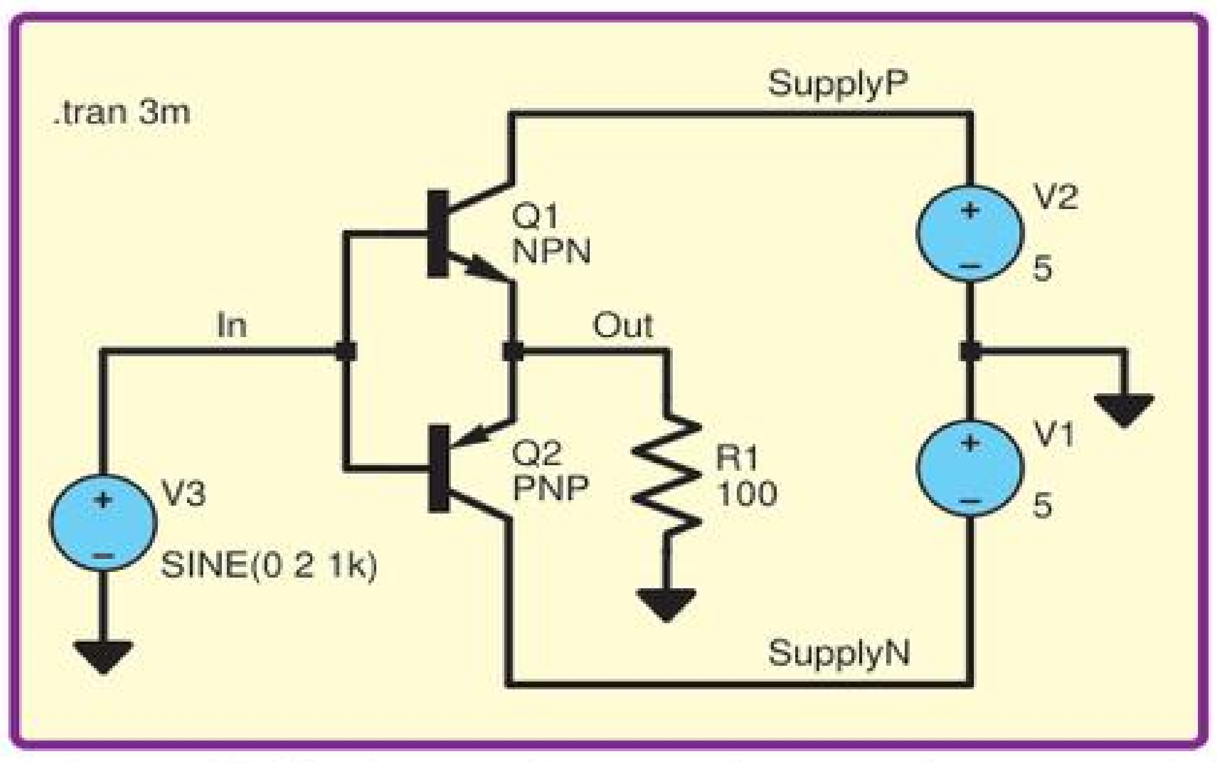


Fig.6. LTSpice schematic used to model Fig.5. This uses default transistor models, not ones of specific real devices

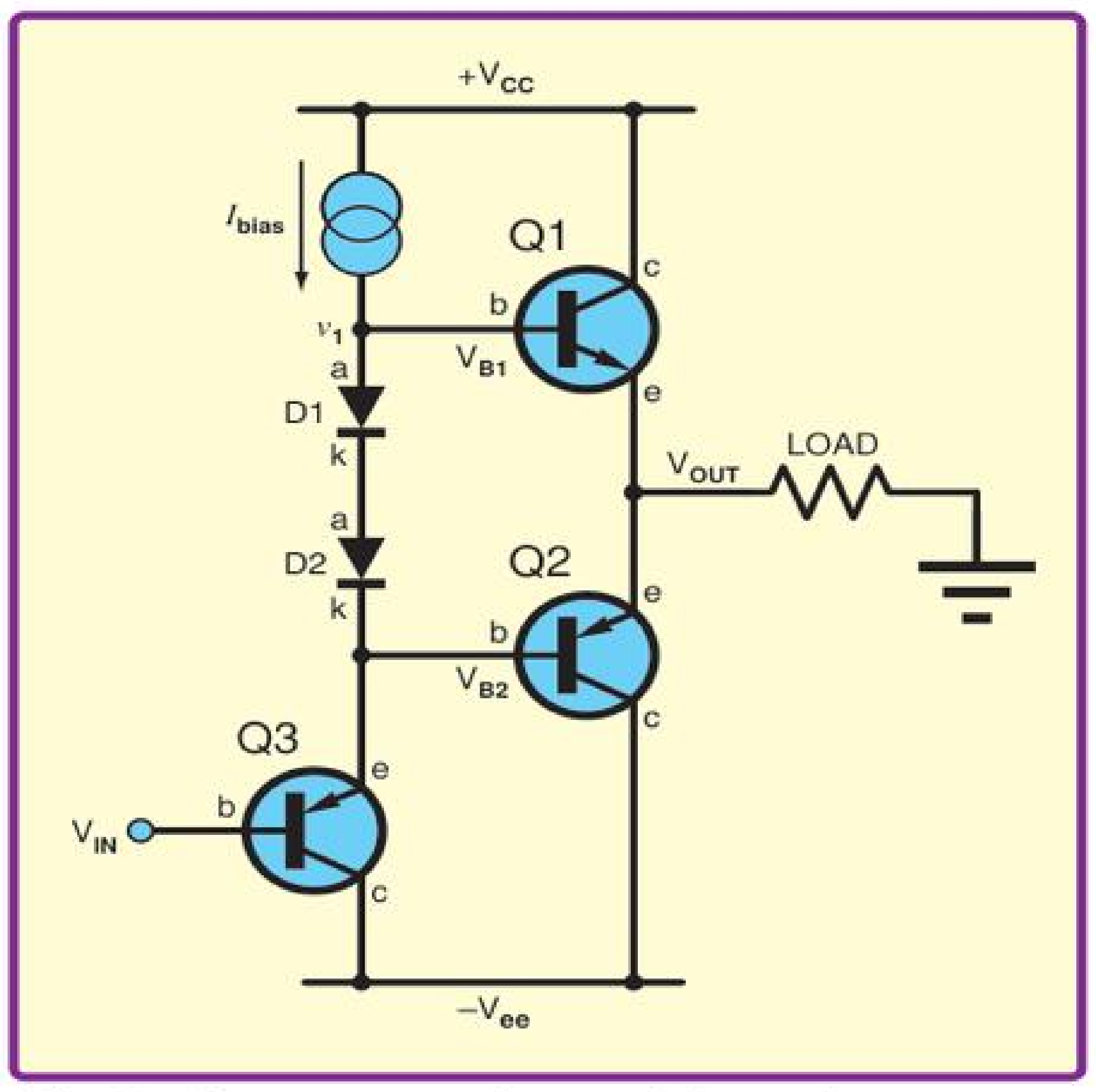


Fig.7. Output transistors biased to prevent crossover-distortion. The diodes may also be implemented using transistor base-emitter junctions

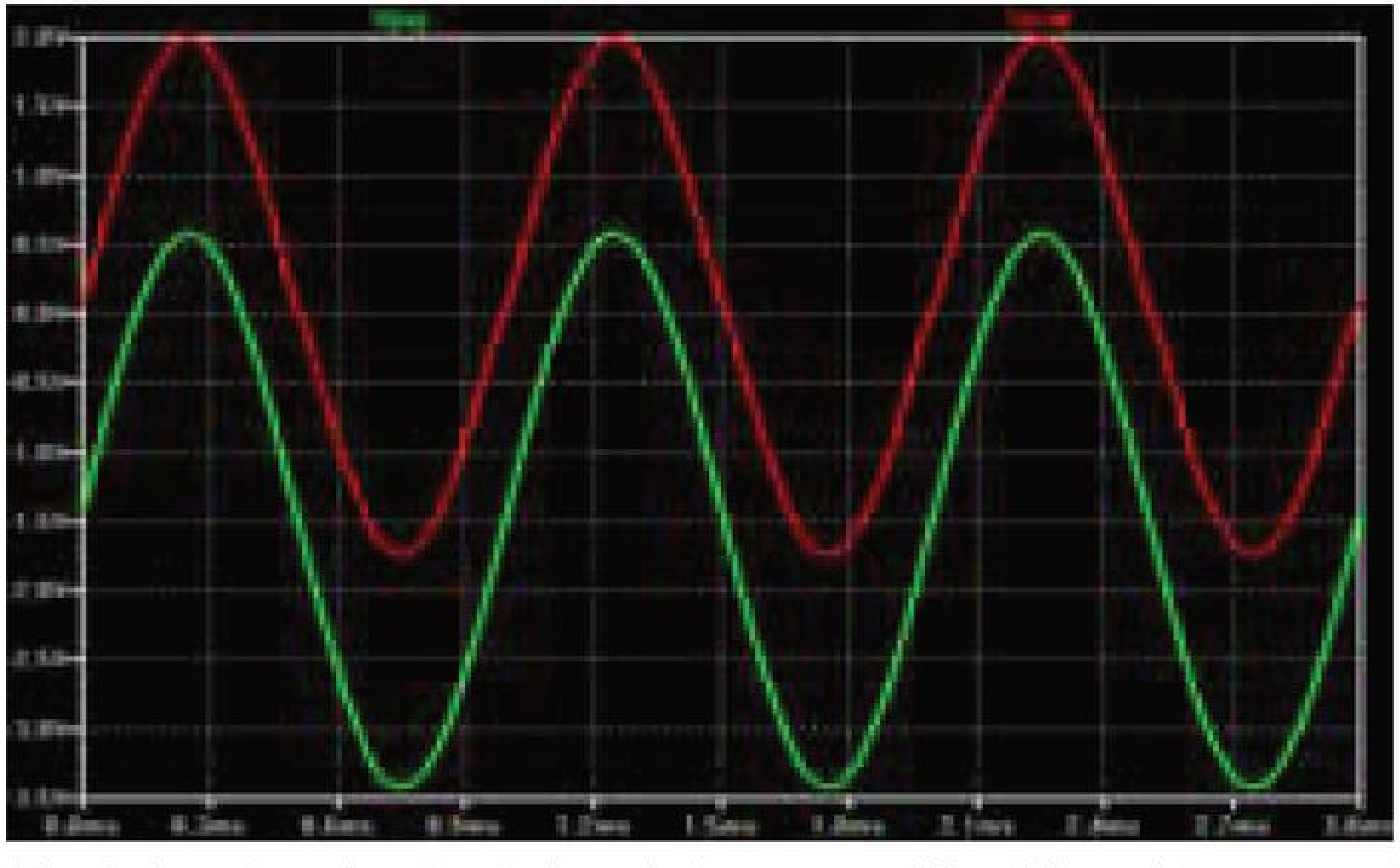


Fig.8. Input and output signals in an amplifier biased to prevent crossover-distortion (LTSpice simulation)

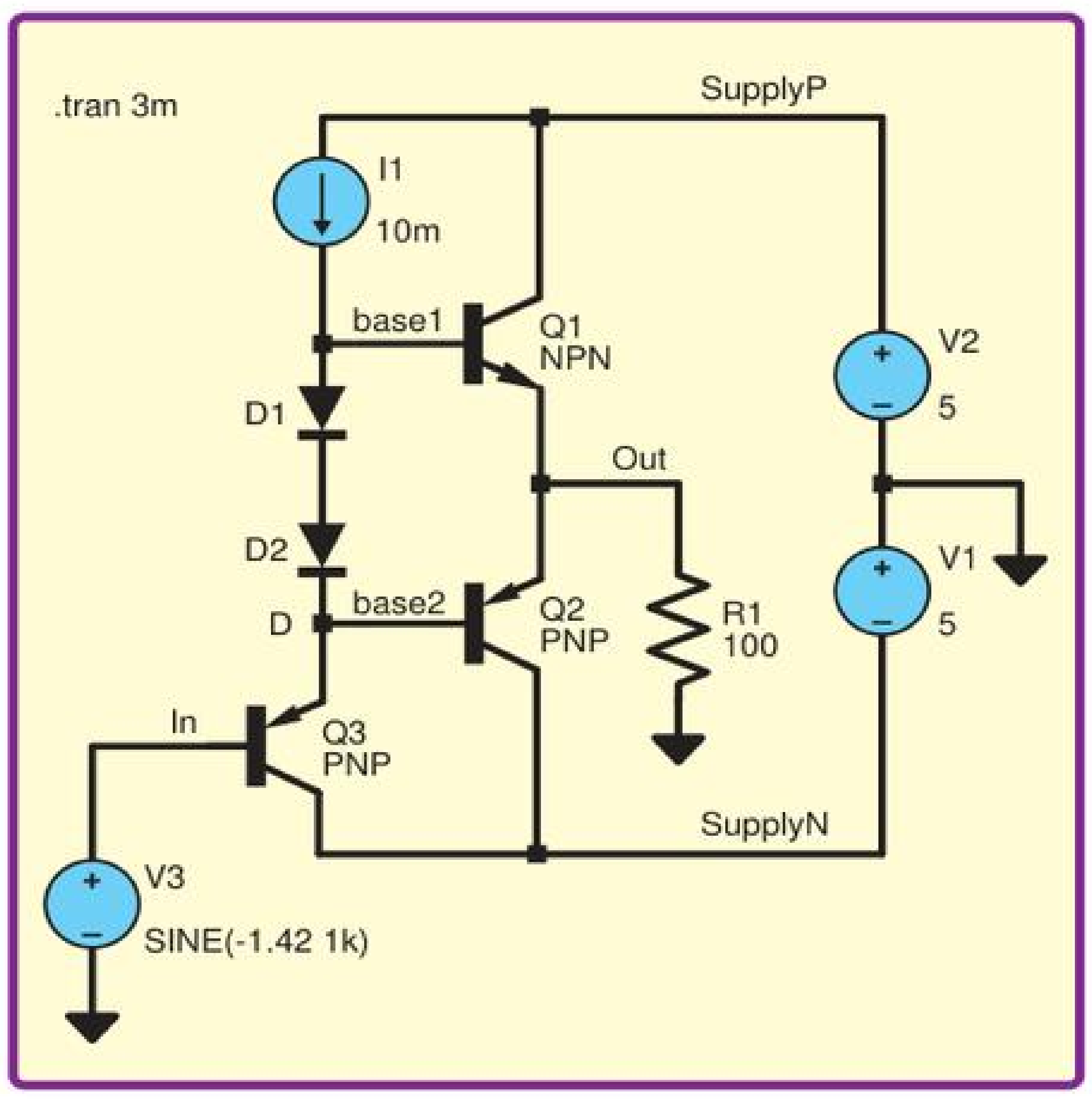


Fig.9. LTSpice schematic used to model Fig.8. This uses default transistor models, not ones of specific real devices

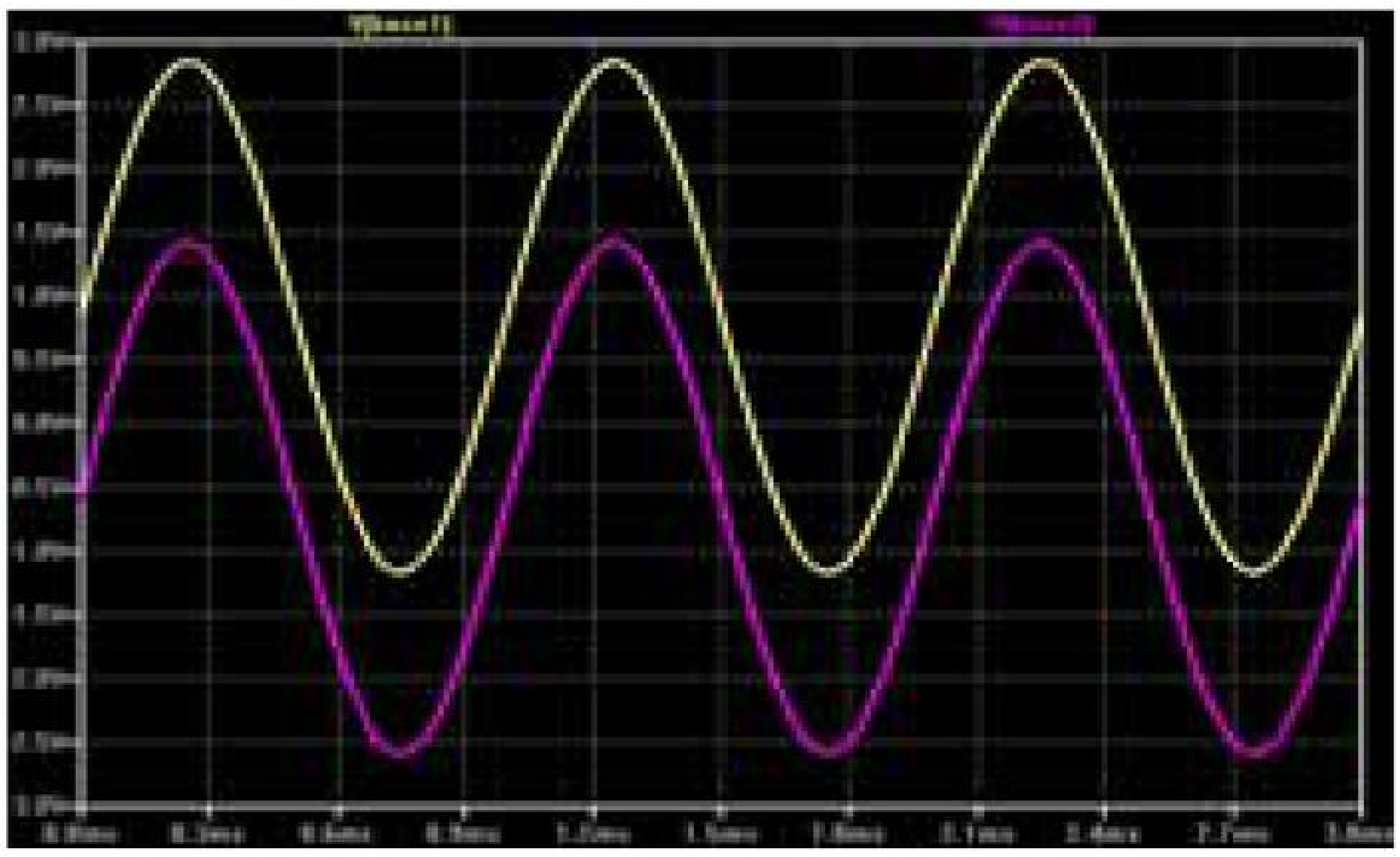


Fig.10. Further simulation results from the circuit in Fig.9. This shows the difference base bias voltages for Q1 (yellow trace) and Q2 (magenta trace) (*LTSpice simulation*)

difference in bias voltage required between the transistors' bases (see Fig.7). The diodes are biased with the current required to give the correct V_{BE} value by means of a current source. These are the diodes that afferrari mentions in his sixth question. This circuit operates in class AB – between class A and class B – the transistors are off for less than one half cycle of the waveform.

Fig.8 shows the input (V_{IN}, green trace) and output signals (V_{OUT}, red trace) for the circuit in Fig.7, simulated in LTSpice using default models. The LTSpice schematic is shown in Fig.9. The output waveform in Fig.8 shows that the crossover-distortion has been almost completely eliminated (there is still a slight kink in the waveform).

In Fig.9, we can see that the output signal is centred on 0V, as we would want. However, the input signal has a bias level of about –1.4V (two diode/V_{BE} 0.7V drops). The V_{BE} voltage of Q3 means the bias voltage on Q2's base is about –0.7V and the diode voltage drops mean that Q1's base has a bias of about +0.7V. This is illustrated in Fig.10, which shows the base voltages of Q1 and Q2 from the same simulation.

As the input signal varies, the diodes maintain a constant 2×V_{BE} *difference* between the two base voltages (Q1, Q2). The actual base voltages will vary with the signal, but the difference between them is fixed by this biasing arrangement. The diodes are ideally at the same temperature as the output transistors, so that any changes in their voltage drop with temperature track those of the output transistors.

Some protection

The push-pull amplifier is likely to be damaged if its output is short-circuited to ground, due to excessive collector current which will flow in the conducting transistor. Short-circuit protection circuitry may be added to overcome this problem (see Fig.11). The protection circuitry monitors the current flowing in the output and turns off the output transistor if the current exceeds some pre-defined limit.

The current detection is achieved by using a small resistor in the output signal path, and a transistor to switch off the output. The output current causes a voltage drop across the resistor. A protection transistor switches on when the resistor voltage reaches about 0.6V to 0.7V. The protection transistor is connected so that when it is on it effectively short-circuits the input to the output transistors, so they have no signal to amplify.

The protection resistor values, R_{p1} and R_{p2} may be chosen using $R_{p1} = R_{p2} = V_{beQp1}/I_{max}$ where V_{beQp1} is the turn-on voltage of the protection transistor (typically 0.6V to 0.7V) and I_{max} is the maximum output current, ie, the current at which the protection kicks in. Protection circuits such as this are what enable op amps to have the 'infinite output short circuit duration' quoted on many data sheets.

Buffer biasing

As indicated in atferrari's sixth question, the diode-based biasing in the circuit of Fig.7 is difficult to implement, at least with discrete components. It is difficult to set the required voltage by manipulating the diode current, which is temperature sensitive. Keeping all the diodes and transistors at the same temperature, so that their characteristics track one another, is also difficult. When designing a silicon chip the situation may be different, due to the different constrains and opportunities in the design process.

Biasing of the buffer can also be achieved using what is known as a V_{BE} multiplier (also known as an amplified diode) as shown in Fig.12 (Qb, R3 and R4). The bias is adjustable using R3 to give the required quiescent current for the circuit (the degree to which the output transistors are 'just on' with no signal). The circuit is still temperature sensitive and Qb should be mounted near Q1 and Q2 (eg, on a heatsink).

The V_{BE} multiplier circuit consists of Q_b and resistors R3 and R4. The voltage V_{bias} is effectively fixed by virtue of the fact that Qb's V_{BE} voltage does not vary very much, resulting in a fixed voltage across R4 and hence a fixed current through it.

If the resistors R3 and R4 are chosen so that their current is much larger than Q_b's base current, then we can assume all of the current in R4 also flows in R3. Thus, the total dropped across R3 and R4 (ie, V_{bias}) is equal to V_{BE} multiplied by the ratio of the total resistance of R3 and R4 to the value of R4:

$$V_{bias} = \frac{V_{BE}\left(R3 + R4\right)}{R4}$$

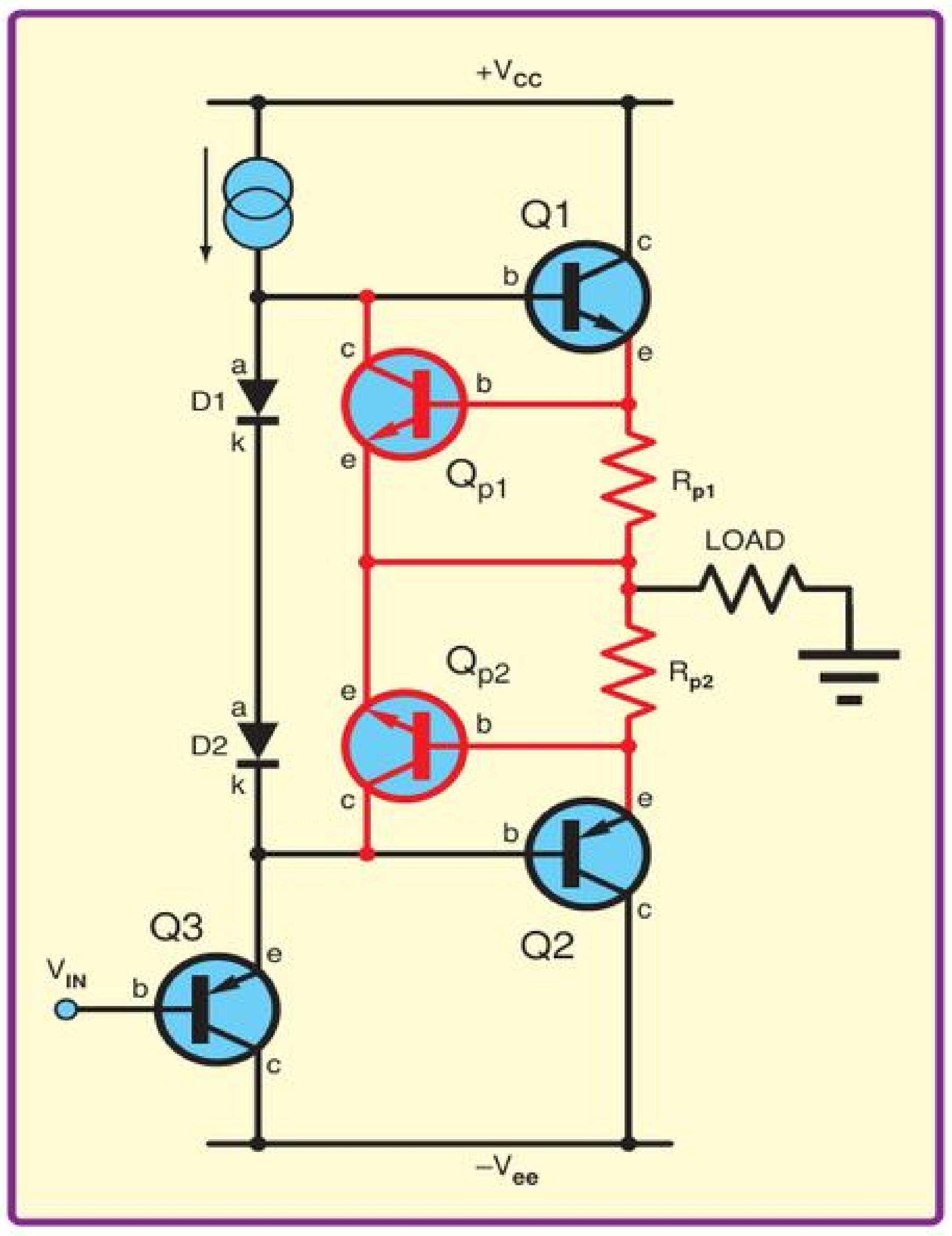


Fig.11. Output buffer with protection circuit (protection circuit is shown in red)

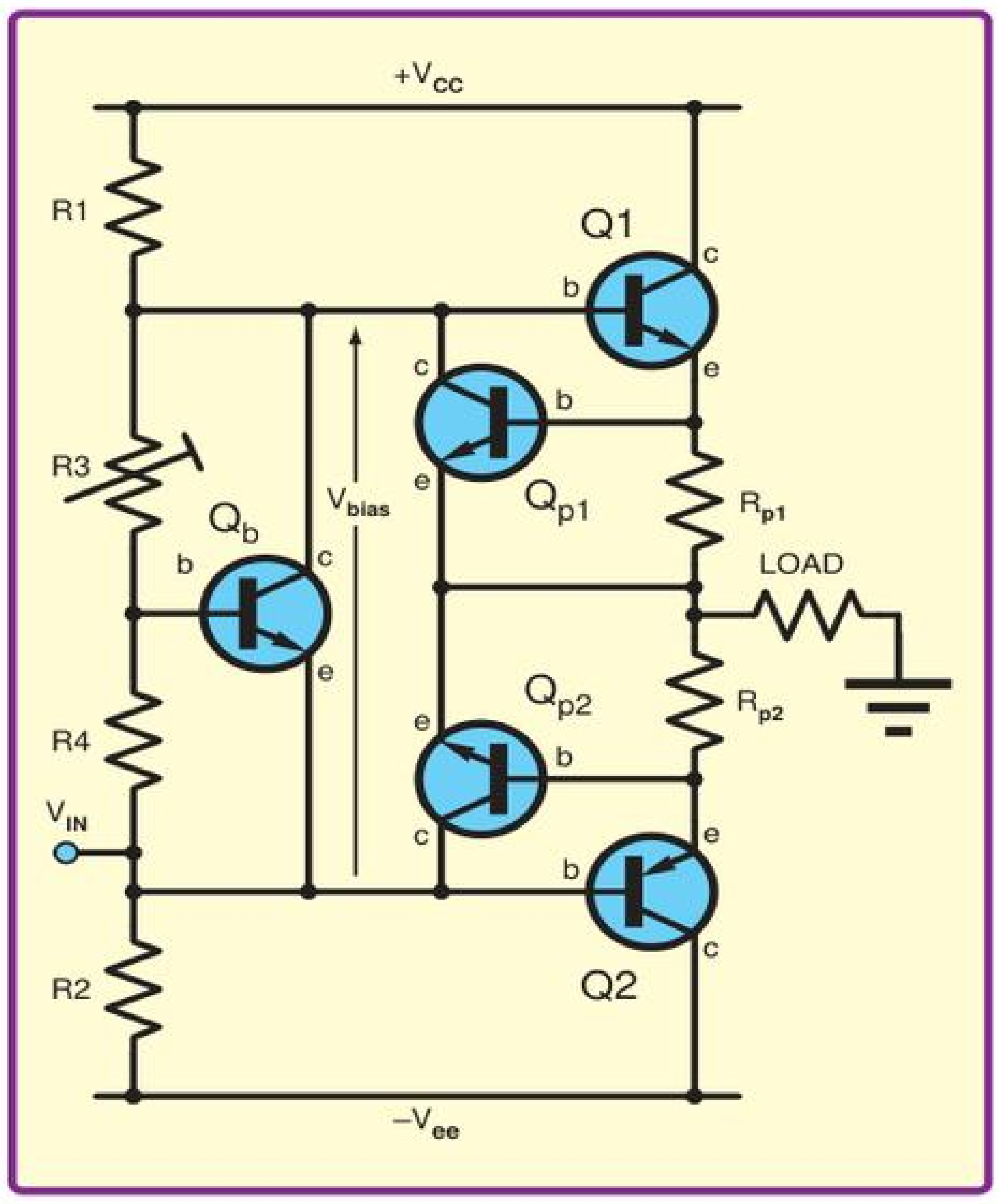


Fig.12. Output buffer using V_{BE} multiplier for biasing instead of diodes

2012.
Olympic year

PIC
PIC32
dsPIC
ARM
AVR

Join the winning team!

The spirit of the Olympic Games is to unite all nations. We united all architectures under mikroC™, mikroBasic™ and mikroPascal™ compilers. Despite their differences, all of them share the same IDE and the same libraries, making a brave step out in compiler philosophy.

MikroElektronika
DEVELOPMENT TOOLS | COMPILERS | BOOKS

GET IT NOW
www.mikroe.com

Practically Speaking

Robert Penfold looks at the Techniques of Actually Doing it!

Be patient…

FEAR of failure is probably one of the biggest disincentives to actually 'taking the plunge' and starting any creative hobby. Rather than a minor masterpiece you could end up with a painting that looks like nothing at all to anyone but yourself; your first piece of carpentry could look like a joke piece, or your first electronic project might do nothing more than run down batteries!

Being realistic about matters, these fears are not totally unfounded in that things can go wrong, and there is no guarantee that you will be at least reasonably competent at any pastime you undertake. There are certainly no 'cast iron' guarantees that a completed project can be made to function by a beginner who lacks any technical knowhow and test equipment.

On the positive side, the chances of success are actually very good these days. In the past, some methods of construction were awkward and not always as reliable as one would have hoped. There were also some dodgy components on sale. These days, faulty electronic components are extremely rare indeed, and there should be no problems with parts obtained from reputable sources. There are now relatively few construction methods in common use, and those that remain are relatively straightforward and reliable.

Avoiding trouble

One possible exception here is surface-mount technology, which can be tricky due to the minute components used. Ideally, this method of construction requires some specialised equipment, and it is not really a good starting point for newcomers to electronics. Initially, it is probably best to avoid any project that has any obviously awkward or specialised aspects to its construction. A simple project that is fairly straightforward in every aspect of construction gives a much better chance of success, and provides a useful platform for moving on to more difficult projects.

It also helps to avoid problems later if you bear in mind that building a project is not a race. It is tempting to rush at things and try to get the project completed as quickly as possible, but with any creative pastime it is much better to take a measured approach. The purpose of project construction is to produce a neat finished unit that works well, and this is not likely to be the outcome if the job is rushed. With an impatient approach to matters, it could well be a case of 'more haste, less speed'.

I make no apologies for repeating the oft-given warning that beginners should **NOT** build mains-powered projects. Building mains-powered projects is *dangerous* unless you know exactly what you are doing, and there is a risk of beginners producing a finished unit that is not safe to use.

Checking for faults on mains-powered equipment has to be regarded as a high risk occupation. By contrast, battery powered projects should be safe to build and use, and fault-finding should be equally safe if the finished unit fails to work properly.

Another way of avoiding problems with finished projects is to check for errors at each step of construction. Check that you have the right component and that you are fitting it in the right place on the circuit board, before soldering it into place. Having fitted a component, check that it is actually where you intended to fit it, and that all the pins or leads have been soldered to the circuit board.

A desoldering tool should be considered an essential part of the electronic project building toolkit, but having to correct errors on circuit boards is best avoided. The tiny copper tracks and pads of modern printed circuit boards (PCBs) are not particularly tough and are easily damaged when removing and refitting components. It is definitely best to get it right first time.

In a fix

Unfortunately, there is no absolute guarantee of success even if you proceed carefully and meticulously, checking everything as you go along. Although you could reasonably consider yourself to be very unlucky if the painstaking approach does not result in a project that works first time. When a newly constructed project is clearly not working properly, you *must not* leave it switched on. The fault might cause high currents to flow somewhere in the circuit, which could easily lead to some expensive damage unless the power is switched off quite quickly.

If the circuit is only intended to operate at low power levels and there is the characteristic smell of hot components, the unit should definitely be switched off at once. Furthermore, it should not be switched on again until the likely cause of the problem has been found and fixed.

A multi-range test meter, or 'multimeter' as it is often called, used to be an expensive piece of equipment, and in the case of a top notch professional unit it still is. However, quite sophisticated digital units can now be obtained at comparatively low prices, and will last a long time if handled and used carefully. Even if you do not have a great deal of technical expertise, an inexpensive multimeter can be extremely useful, especially if it includes some component testing facilities.

If you have a multimeter, it is a good idea to check the current consumption of a new project when it is first switched on. Switch off at once if current flow is clearly 'over the top'. It should be safe to leave the unit switched on so that some further checks can be made in cases where the current consumption is either very low or much as expected. Without some technical expertise, it is not possible to make a series of voltage checks on the circuit to help track down the problem. However, a multimeter can still be very useful when trying to locate faults.

For example, you can check that the supply is reaching the on/off switch, and getting to the circuit board when the unit is switched on. Faulty components are something of a rarity these days, but battery clips that do not connect properly are not exactly unknown, and some 'cheap as chips' switches are perhaps not quite as reliable as they should be.

Using a multimeter you can check that the supply is present and correct, that it is reaching the supply pins of the integrated circuits, and that it is reaching other appropriate points on the circuit board. Even the most basic of multimeters, analogue or digital, should have a continuity tester function. This can be used to check for short circuits and breaks in the wiring or the copper tracks on a circuit board.

Faulty components are very rare these days, but components can be damaged in transit or when they are being connected to the circuit board. It is advisable not to use any components that look in any way suspect. Obviously, something superficial like worn markings is not important provided the value of the component can still be read properly.

With anything more than this, it is best to assume that a component is faulty, unless you have some way of testing it. This is where the component testing facilities of some digital multimeters can be very useful. Any multimeter should be able to measure a wide range or resistance ranges, and most also have facilities for making some basic tests on transistors and diodes. It is well worthwhile having a multimeter that includes capacitance ranges (Fig.1), even if it means paying a little extra.

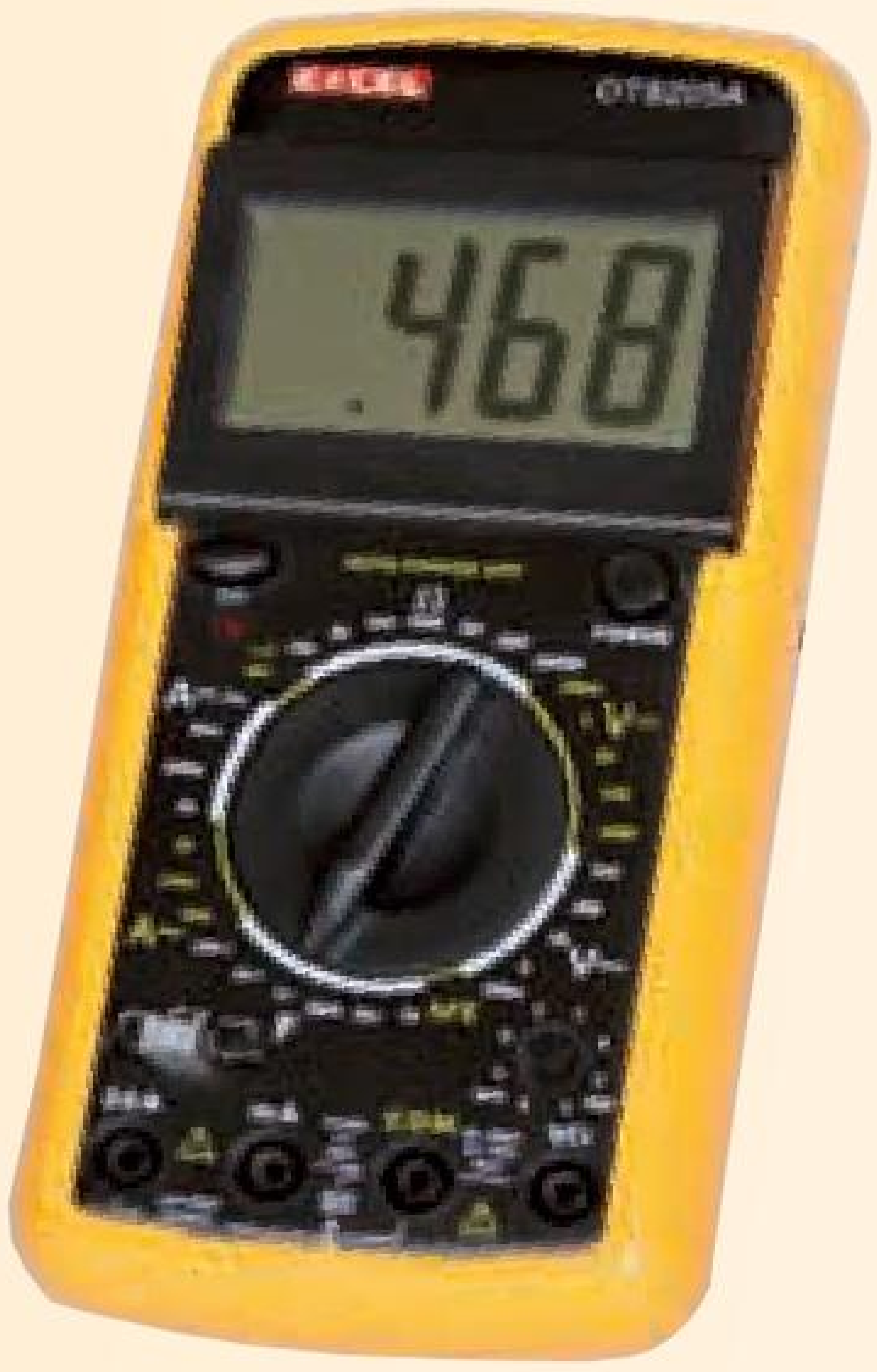


Fig.1. An inexpensive multimeter can be useful when things go wrong, especially if it has some component testing capabilities. This one can measure a wide range of capacitance values in addition to the usual resistance measuring ranges

Hot point

Taking too long to solder components in place can damage them due to overheating, but in outward appearance there may not be any major signs of damage. However, if a component has been subjected to too much heat it will usually change colour slightly.

Also, its appearance will usually be noticeably shinier or duller. It is probably worthwhile replacing any component that looks a little 'off colour'. Even if a 'cooked' component does actually work, it is likely that its reliability will have been impaired.

Mistakes are easily made when picking out the required component from a set of parts. Variations on the standard four band method of marking resistor values are unhelpful, and the value markings on capacitors seem to be ever more cryptic. In some cases the latter are inconclusive. For example, '220' means a value of 22 picofarads with one method of marking (22 and no multiplier), but it simply means the more obvious 220 picofarads with another method. Once again, a multimeter having a set of capacitance ranges can sort out this type of thing, preferably prior to fitting the components rather than after the completed project has gone awry.

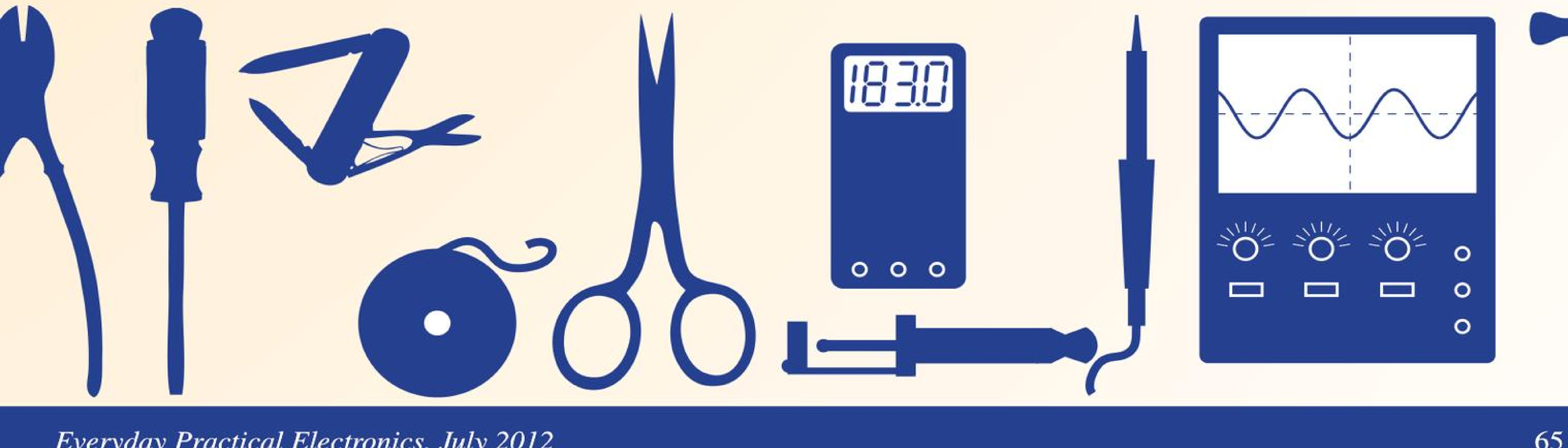
There are numerous sites on the Internet that have details of the resistor colour codes, the various methods of marking the values of capacitors, and transistor leadout configurations. If you are uncertain about something of this type, the answer is probably on at least one Internet site, and more probably on hundreds or thousands of them!

Clean sweep

Experience suggests that the most likely cause of faults on a circuit board is accidental 'short circuits' on the underside of the board. PCBs have become more intricate over the years, and this has greatly increased the risk of short circuits between the copper tracks and pads due to small blobs or trails of excess solder (Fig.2). Cleaning and thoroughly checking boards for short circuits is something that should be done as soon as they are finished, but it is worth repeating the process when a completed project fails to work.

Excess flux tends to accumulate on the underside of circuit boards, making it difficult to see small pieces of excess solder. This is why it is important to clean boards before making a visual inspection for short circuits. Excess flux can be removed using special cleaning fluids, but simply scrubbing the underside of the board using an old toothbrush seems to work just as well. This second method has the advantage that it will probably remove any loose pieces of solder that are causing problems.

Even if you have good eyesight, it is likely that a fair percentage of solder blobs or trails will be difficult or impossible to spot. A loupe or magnifying glass greatly increases the chances of finding solder bridges. Any solder bridges that are found can usually be wiped away using the hot tip of a soldering iron, but large amounts of excess solder should be removed using a proper desoldering tool, such as the suction pump variety.



When inspecting the underside of the board, it makes sense to keep a look-out for any other problems. With modern solders and components you would probably find it very difficult to produce a bad ('dry') soldered joint, even if you were trying to do so, but they can still occur. Look for joints that are misshapen, have an obvious lack of solder, or where the solder has a dull surface instead of the normal shiny type. It is best to remove the solder from any suspect joints and redo them. Are there any really 'dry' joints, which are the ones you have forgotten to solder? In the case of a stripboard, have all the breaks in the copper strips been cut properly? A very fine line of copper is all that is needed to maintain continuity and prevent a project from working properly.

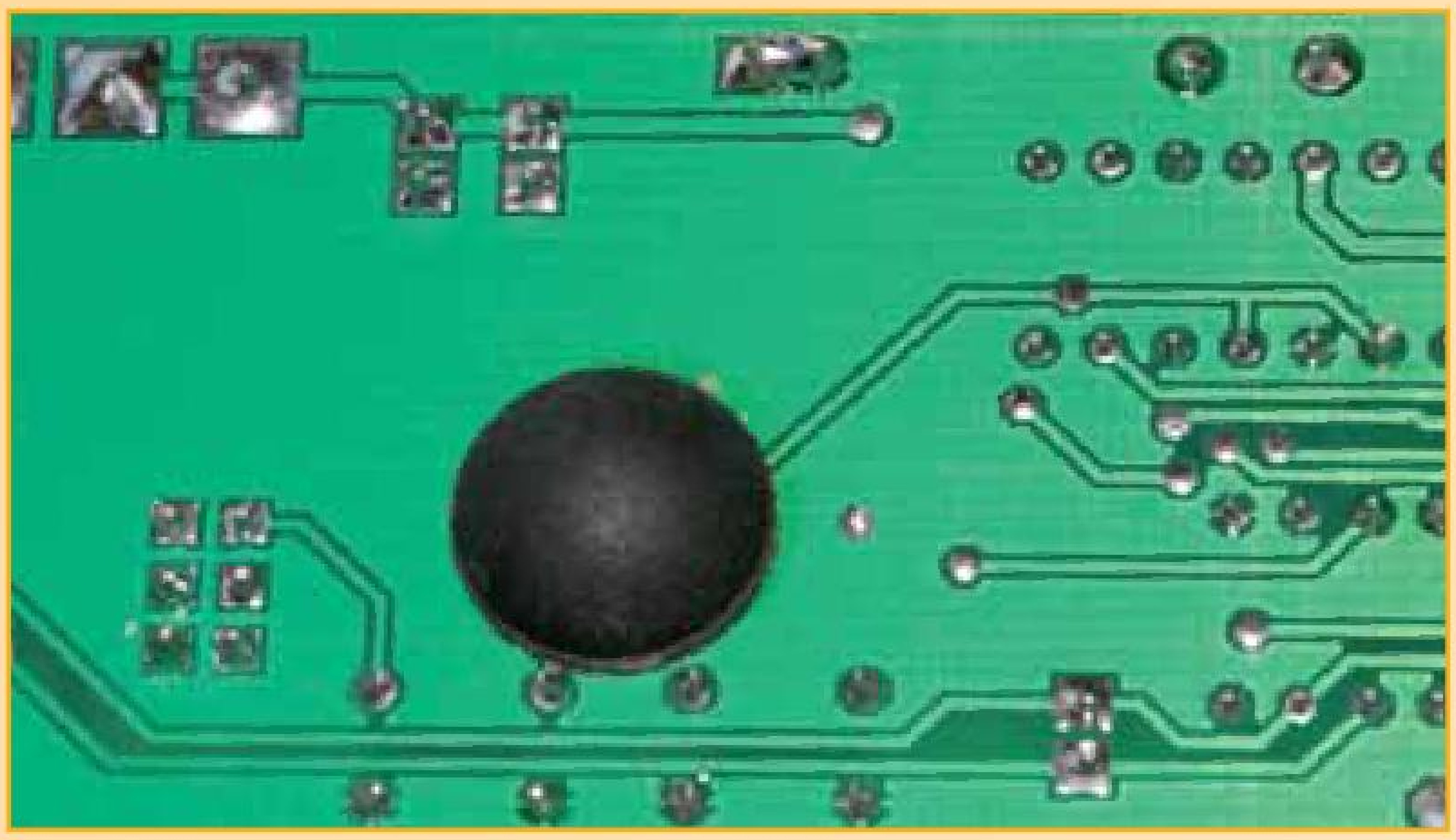


Fig.2. This board might look all right at first glance, but the large joint at the top centre should actually be two separate joints. An LED is being short-circuited, preventing it from working

Double checking

When you are certain that there are no problems on the underside of the board, recheck the component layout. Have components such as electrolytic capacitors, diodes, transistors and integrated circuits been fitted the right way round? The correct orientation is fairly obvious in most cases, but we are all capable of making occasional mistakes. Have the leadout wires of a transistor become crossed over and fitted in the wrong holes? Many components, but particularly capacitors and integrated circuits, have extraneous markings and moulding marks that can be confusing. Look carefully at the components to check that you are not misinterpreting something.

Take a close look at the notches, dimples, lines, or whatever that indicate pin one of an integrated circuit. Integrated circuits are notorious for confusing markings and moulding marks, but a careful visual inspection should enable you to see which mark or marks are the relevant ones. If an integrated circuit becomes hot as soon as a project is switched on, then it is quite likely that it is fitted with the wrong orientation. In fact, many integrated circuits will virtually short circuit the supply if they are fitted the wrong way around.

If at all possible, get someone else to double-check the circuit board and any wiring. Ideally, this requires someone with a certain amount of technical knowledge, but practically anyone can do some basic checking. Having fooled yourself into getting something wrong once, there is a tendency to keep making the same mistake. A 'fresh pair of eyes' will often spot the error straight away.

Where it is not possible to get someone else to check the project for you, put it to one side for a day or two and then check it again yourself. An error you kept overlooking previously will often become glaringly obvious when you take a fresh look at the project.

Significant errors in *EPE* project articles are few and far between, but it might be worth making enquiries if the checking process reveals something that does not look quite right in the published design. This could be something like a discrepancy between the circuit diagram and the construction diagrams, or a printed circuit overlay that has (say) two R1s and no R7. The publisher will often be able to supply a quick answer with problems such as these. In most cases though, there will be no errors in the article, and your project will work if it properly matches the published design. It pays to keep this in mind when dealing with a faulty project.

Need a small and cost-effective device? Look no further.

PoScope Mega1+

Smallest USB 2.0 portable 1MS/s oscilloscope
Data acquisition of analog and digital signals
Data recording
Export to CSV, XLS, PDF and HTML
Simple usage of advanced features
Examples for C++, VB, Delphi and LabView
Free software and updates

PoKeys 56

Smallest USB HID or ETHERNET I/O interface
Keyboard and joystick simulator (USB)
55 digital I/O (configurable)
LCD and LED matrixes driver
6 PWM outputs, 26 encoder inputs
Supports up to 10 I2C, 1-Wire sensors,
up to 7 analog sensors
Expandable with PoNet
Free software and web interface (Ethernet)

Visit www.poscope.com

PoLabs

EPE IS PLEASED TO BE ABLE TO OFFER YOU THESE

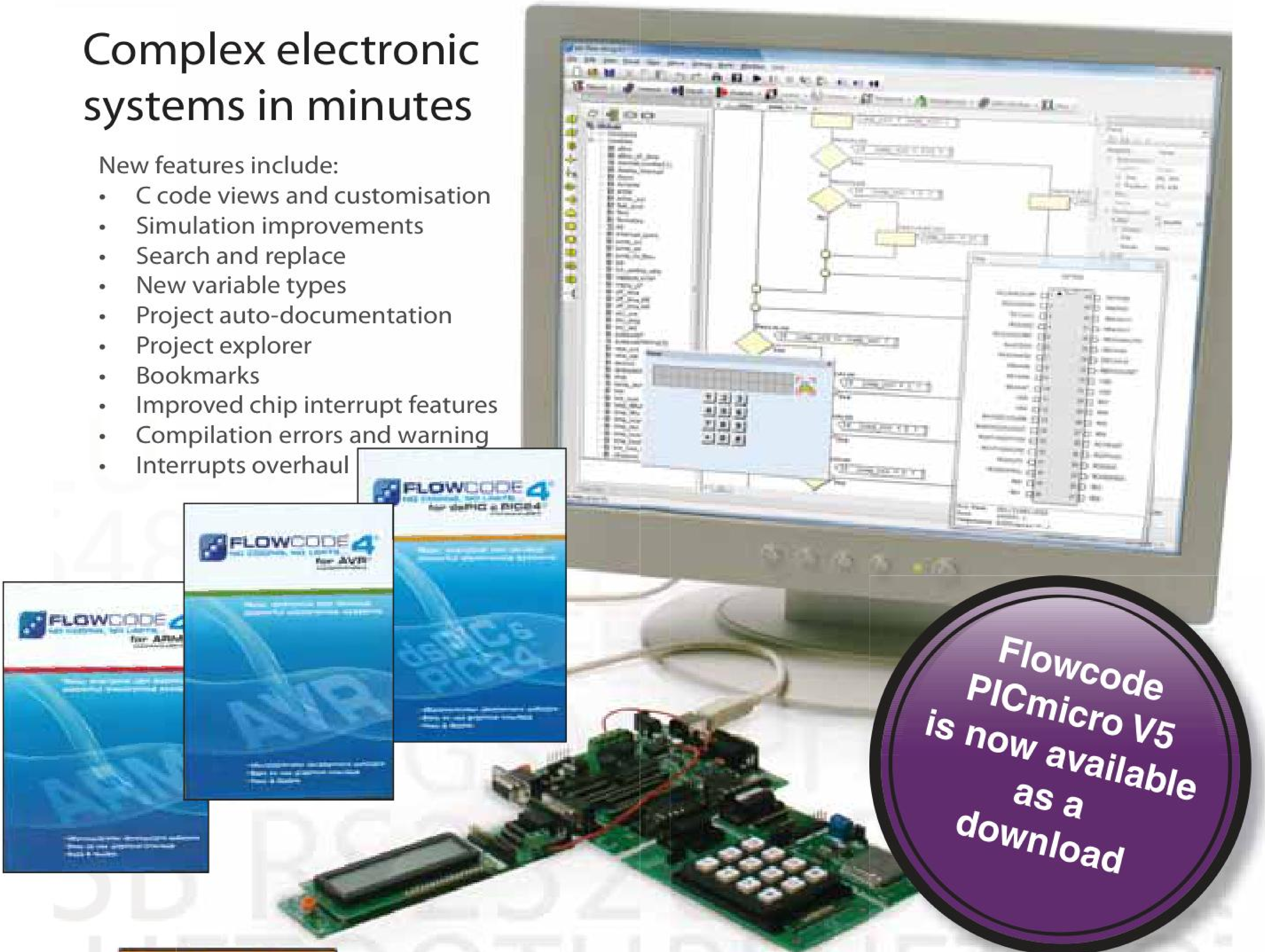
ELECTRONICS CD-ROMS

FLOWCODE 5

Complex electronic systems in minutes

New features include:

- C code views and customisation
- Simulation improvements
- Search and replace
- New variable types
- Project auto-documentation
- Project explorer
- Bookmarks
- Improved chip interrupt features
- Compilation errors and warning
- Interrupts overhaul



Flowcode PICmicro V5 is now available as a download

FLOWCODE 5 PICmicro
MATRIX FlowKit

The FlowKit can be connected to hardware systems to provide a real time debug facility where it is possible to step through the Flowcode program on the PC and step through the program in the hardware at the same time. The FlowKit can be connected to your own hardware to provide In-Circuit Debug to your finished designs.

PRICES **Prices for each of the CD-ROMs above are:**

(Order form on third page)

(UK and EU customers add VAT to 'plus VAT' prices)

	Flowcode 4 AVR/ARM/DSPIC & PIC24	Flowcode 5 PICMICRO Download only
Hobbyist/Student	£45.95 inc. VAT	£58.80 inc. VAT
Professional (Schools/HE/FE/Industry)	£149.00 plus VAT	£199.00 plus VAT
Professional and Flowkit bundle	N/A	£216.00 plus VAT

Please note: **Due to popular demand, Flowcode PICmicro V5 is now available as a download. Please include your email address and a username (of your choice) on your order. A unique download code will then be emailed to you. If you require the CDROM as a back-up (available June 2012) then please add an extra £14 to the above price.**

PICmicro TUTORIALS AND PROGRAMMING

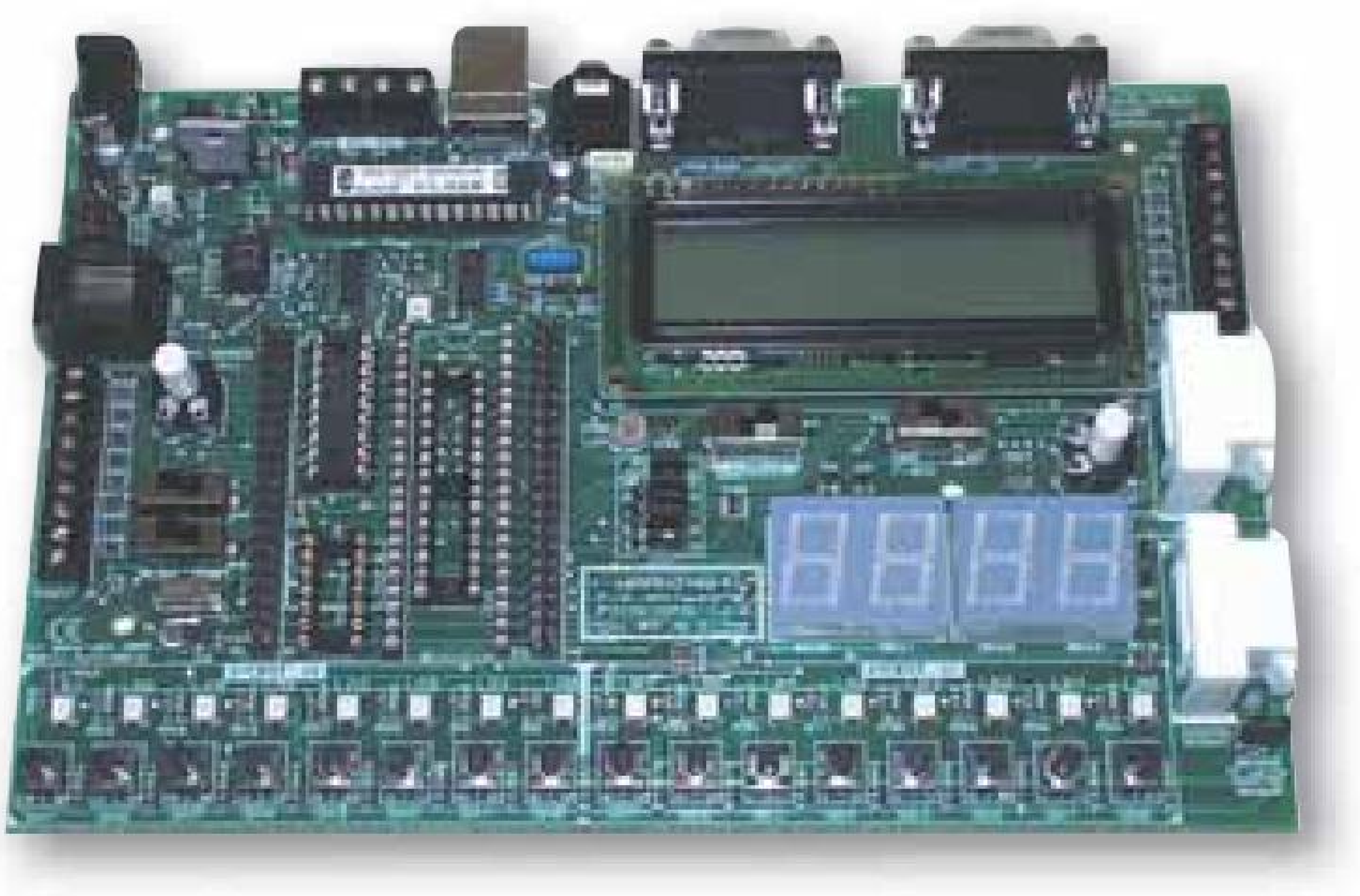
HARDWARE

VERSION 3 PICmicro MCU development board

Suitable for use with the three software packages listed below.

This flexible development board allows students to learn both how to program PICmicro microcontrollers as well as program a range of 8, 18, 28 and 40-pin devices from the 12, 16 and 18 series PICmicro ranges. For experienced programmers all programming software is included in the PPP utility that comes with the development board. For those who want to learn, choose one or all of the packages below to use with the Development Board.

- Makes it easier to develop PICmicro projects
- Supports low cost Flash-programmable PICmicro devices
- Fully featured integrated displays – 16 individual LEDs, quad 7-segment display and alphanumeric LCD display
- Supports PICmicro microcontrollers with A/D converters
- Fully protected expansion bus for project work
- USB programmable
- Can be powered by USB (no power supply required)



£161 including VAT and postage, supplied with USB cable and programming software

SOFTWARE

ASSEMBLY FOR PICmicro V4

(Formerly PICtutor)

Assembly for PICmicro microcontrollers V3.0 (previously known as PICtutor) by John Becker contains a complete course in programming the PIC16F84 PICmicro microcontroller from Arizona Microchip. It starts with fundamental concepts and extends up to complex programs including watchdog timers, interrupts and sleep modes.

The CD makes use of the latest simulation techniques which provide a superb tool for learning: the Virtual PICmicro microcontroller, this is a simulation tool that allows users to write and execute MPASM assembler code for the PIC16F84 microcontroller on-screen. Using this you can actually see what happens inside the PICmicro MCU as each instruction is executed, which enhances understanding.

● Comprehensive instruction through 45 tutorial sections ● Includes Vlab, a Virtual PICmicro microcontroller: a fully functioning simulator ● Tests, exercises and projects covering a wide range of PICmicro MCU applications ● Includes MPLAB assembler ● Visual representation of a PICmicro showing architecture and functions ● Expert system for code entry helps first time users ● Shows data flow and fetch execute cycle and has challenges (washing machine, lift, crossroads etc.) ● Imports MPASM files.

'C' FOR 16 Series PICmicro Version 4

The C for PICmicro microcontrollers CD-ROM is designed for students and professionals who need to learn how to program embedded microcontrollers in C. The CD-ROM contains a course as well as all the software tools needed to create Hex code for a wide range of PICmicro devices – including a full C compiler for a wide range of PICmicro devices.

Although the course focuses on the use of the PICmicro microcontrollers, this CD-ROM will provide a good grounding in C programming for any microcontroller.

● Complete course in C as well as C programming for PICmicro microcontrollers ● Highly interactive course ● Virtual C PICmicro improves understanding ● Includes a C compiler for a wide range of PICmicro devices ● Includes full Integrated Development Environment ● Includes MPLAB software ● Compatible with most PICmicro programmers ● Includes a compiler for all the PICmicro devices.

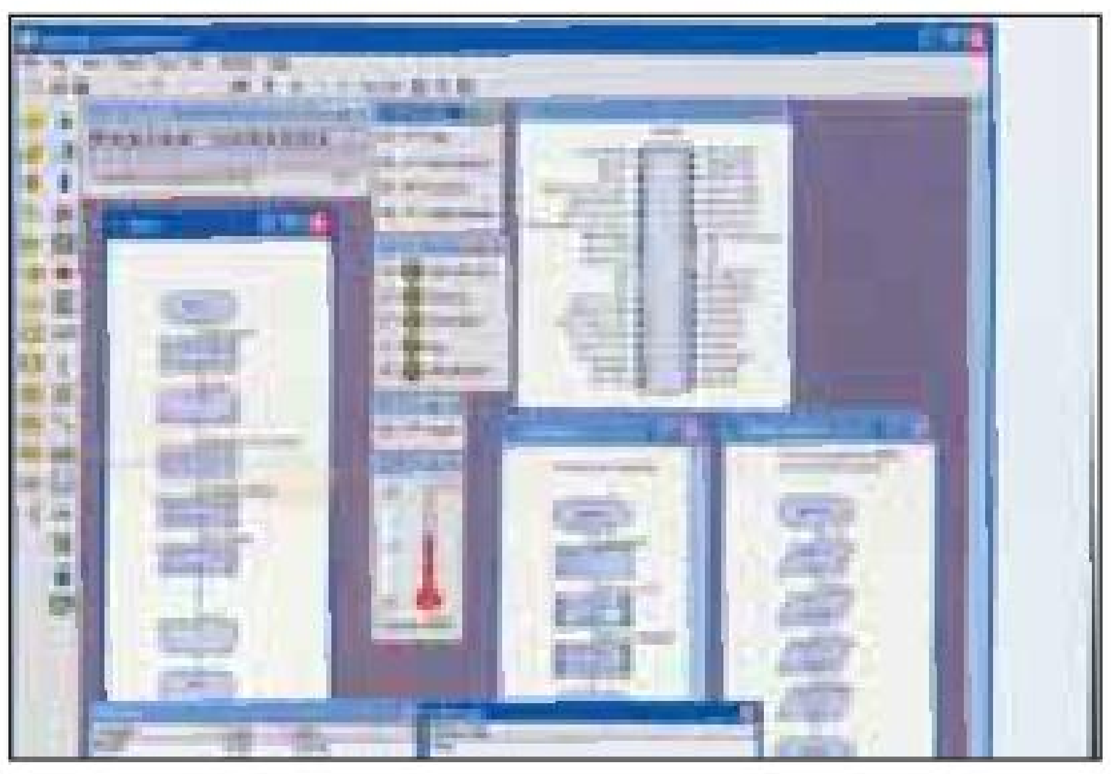
Minimum system requirements for these items: Pentium PC running, 2000, ME, XP; CD-ROM drive; 64MB RAM; 10MB hard disk space.
Flowcode will run on XP or later operating systems

FLOWCODE FOR PICmicro V5 (see opposite page)

Flowcode is a very high level language programming system based on flowcharts. Flowcode allows you to design and simulate complex systems in a matter of minutes. A powerful language that uses macros to facilitate the control of devices like 7-segment displays, motor controllers and LCDs. The use of macros allows you to control these devices without getting bogged down in understanding the programming. When used in conjunction with the Version 3 development board this provides a seamless solution that allows you to program chips in minutes.

- Requires no programming experience
- Allows complex PICmicro applications to be designed quickly
- Uses international standard flow chart symbols
- Full on-screen simulation allows debugging and speeds up the development process.
- Facilitates learning via a full suite of demonstration tutorials
- Produces ASM code for a range of 18, 28 and 40-pin devices
- 16-bit arithmetic strings and string manipulation
- Pulse width modulation
- I2C.

Features include panel creator, in circuit debug, virtual networks, C code customisation, floating point and new components. The Hobbyist/Student version is limited to 4K of code (8K on 18F devices)



PRICES

Prices for each of the CD-ROMs above are:

(Order form on next page)

(UK and EU customers add VAT to 'plus VAT' prices)

Hobbyist/Student	**£45.95**	**inc VAT**
Professional (Schools/HE/FE/Industry)	**£99**	**plus VAT**
Professional 10 user (Network Licence)	**£350**	**plus VAT**
Site Licence	**£699**	**plus VAT**
Flowcode Professional (Schools/HE/FE/Industry)	**£149**	**plus VAT**
Flowcode 10 user (Network Licence)	**£399**	**plus VAT**
Flowcode Site Licence	**£799**	**plus VAT**

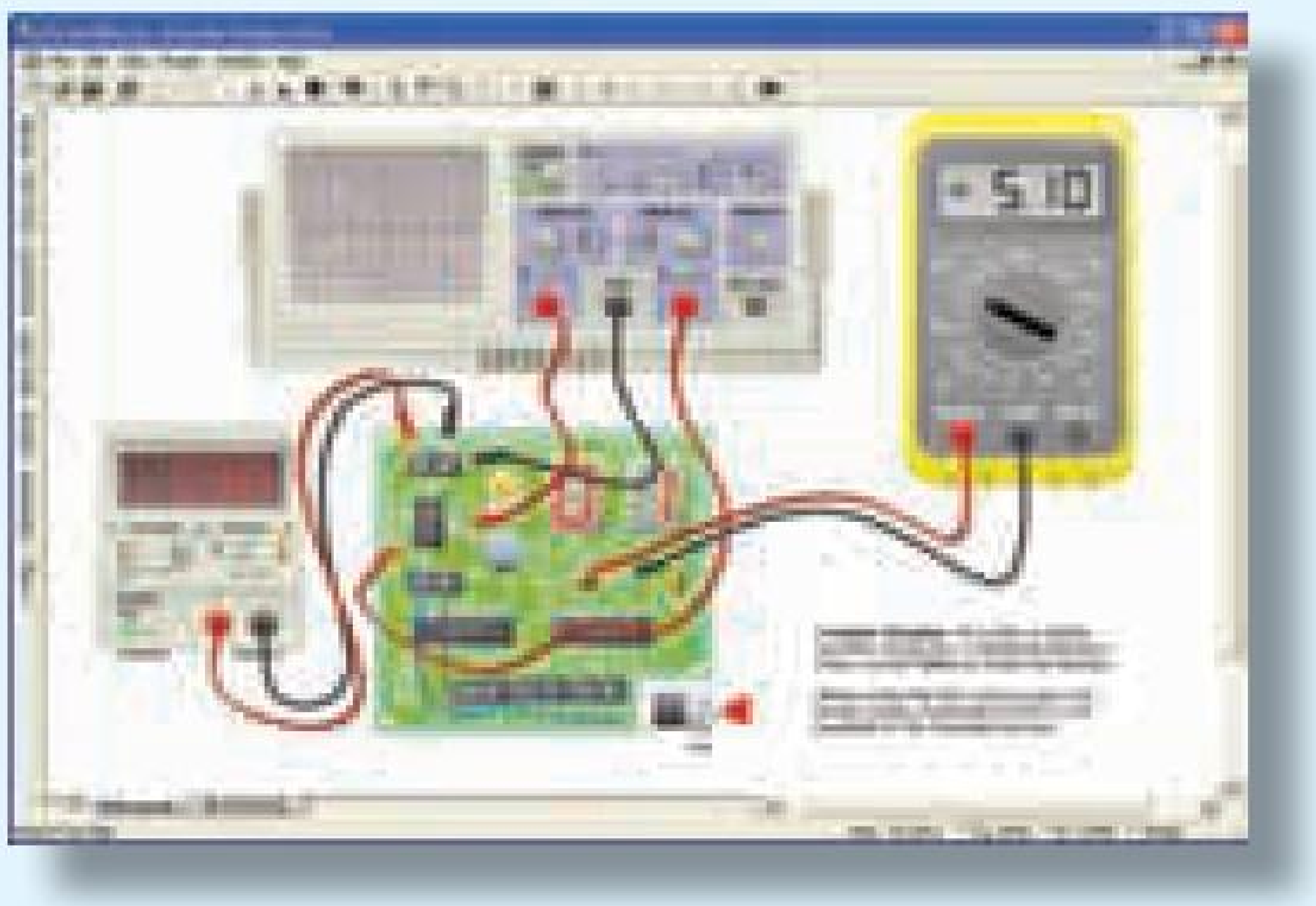
CIRCUIT WIZARD

Circuit Wizard is a revolutionary new software system that combines circuit design, PCB design, simulation and CAD/CAM manufacture in one complete package.

Two versions are available, Standard or Professional.

By integrating the entire design process, Circuit Wizard provides you with all the tools necessary to produce an electronics project from start to finish – even including on-screen testing of the PCB prior to construction!

- *Circuit diagram design with component library (500 components Standard, 1500 components Professional)*
- *Virtual instruments (4 Standard, 7 Professional)*
- *On-screen animation*
- *Interactive circuit diagram simulation*
- *True analogue/digital simulation*
- *Simulation of component destruction*
- *PCB Layout*
- *Interactive PCB layout simulation*
- *Automatic PCB routing*
- *Gerber export*
- *Multi-level zoom (25% to 1000%)*
- *Multiple undo and redo*
- *Copy and paste to other software*
- *Multiple document support*



This software can be used with the *Jump Start* and *Teach-In 2011* series (and the *Teach-In 4* book).

Standard **£61.25** inc. VAT
Professional **£91.90** inc. VAT

Minimum system requirements for these CD-ROMs: Pentium PC, CD-ROM drive, 32MB RAM, 10MB hard disk space. Windows 2000/ME/XP, mouse, sound card, web browser.

EPE PIC RESOURCES V2

Version 2 includes the EPE PIC Tutorial V2 series of Supplements (EPE April, May, June 2003)

The CD-ROM contains the following Tutorial-related software and texts:

- EPE PIC Tutorial V2 complete series of articles plus demonstration software, John Becker, April, May, June '03
- PIC Toolkit Mk3 (TK3 hardware construction details), John Becker, Oct '01
- PIC Toolkit TK3 for Windows (software details), John Becker, Nov '01

Plus 18 useful texts to help you get the most out of your PIC programming.

Price **£14.75** inc. VAT

ELECTRONIC COMPONENTS PHOTOS

NEW VERSION

A high quality selection of over 200 jpg images of electronic components. This selection of high resolution photos can be used to enhance projects and presentations or to help with training and educational material. They are royalty free for use in commercial or personal printed projects, and can also be used royalty free in books, catalogues, magazine articles as well as worldwide web pages (subject to restrictions – see licence for full details).

Now contains Irfan View image software for Windows, with quick-start notes included.

Price **£19.95** inc. VAT

Please send me: CD-ROM ORDER FORM

- ☐ **Assembly for PICmicro V4**
- ☐ **'C' for 16 Series PICmicro V4**
- ☐ **Flowcode for PICmicro V5 (DOWNLOAD + CDROM)**
- ☐ **Flowcode for PICmicro V5 (DOWNLOAD ONLY)**

Email: ....

Username: ....

- ☐ **Flowcode for AVR V4**
- ☐ **Flowcode for ARM V4**
- ☐ **Flowcode for dsPIC & PIC24 V4**

Version required:
- ☐ **Hobbyist/Student**
- ☐ **Professional**
- ☐ **Professional 10 user**
- ☐ **Professional + Flowkit**
- ☐ **Site licence**

Note: The software on each version is the same, only the licence for use varies.

- ☐ **PICmicro Development Board V3 (hardware)**

- ☐ **Circuit Wizard – Standard**
- ☐ **Circuit Wizard – Professional**
- ☐ **EPE PIC Resources V2**
- ☐ **Electronic Components Photos**

Full name: ....
Address: ....
.... Post code: .... Tel. No: ....
Signature: ....

☐ I enclose cheque/PO in £ sterling payable to WIMBORNE PUBLISHING LTD for £ ....
☐ Please charge my Visa/Mastercard/Maestro: £ ....
Valid From: .... Card expiry date: ....
Card No: .... Maestro Issue No. ....
Card Security Code .... (The last 3 digits on or just under the signature strip)

ORDERING
ALL PRICES INCLUDE UK POSTAGE

Student/Single User/Standard/Hobbyist Version price includes postage to most countries in the world
EU residents outside the UK add £5 for airmail postage per order

Professional, Multiple User and Site License Versions – overseas readers add £5 to the basic price of each order for airmail postage (**do not add VAT** unless you live in an EU (European Union) country, then add VAT at 20% or provide your official VAT registration number).

Send your order to:
Direct Book Service
Wimborne Publishing Ltd
113 Lynwood Drive, Merley, Wimborne,
Dorset BH21 1UU
To order by phone ring
01202 880299. Fax: 01202 843233
Goods are normally sent within seven days
E-mail: orders@wimborne.co.uk
Online shop:
www.epemag.com

NET WORK

by Alan Winstanley

Click here to send…

THE advent of colour inkjet printers in the 1990s spurred many computer users to dabble with printing their own stationery, photos and birthday cards at home, reproducing one's handiwork on very expensive printers in a gamut of muddy-looking colours. Making music 'mix' CDs with custom-printed labels, or printing one's own business cards, are also fun DIY computing projects – at least until the novelty wears off.

It's enjoyable and satisfying stuff to begin with, but for many folks it can ultimately become onerous because of the skills and time needed to grapple with a myriad of software and printer options, never mind demanding an endless supply of printer cartridges and consumables. We probably all have dusty piles of CD labels and blank Avery printer labelstock somewhere, a legacy from more enthusiastic times when the home-made 'look and feel' of our efforts occasionally left us feeling slightly short-changed but happy nevertheless.

Snap to it

Today, many creative projects can be moved online, eliminating the need to struggle with design software or temperamental printers, and glossy professional-looking results can be delivered effortlessly to your door with a mouse-click and a wave of a charge card. The future trend is crystal clear, and it relies heavily upon Internet access. For example, birthday cards can be created online using sites such as **Moonpig.com**, which offers a wide range of templates that can be personalised with text and photos, easily uploaded over the web.

Snapshots taken by a mobile phone or digicam can soon be embedded into the card, then add some witty text, select the typeface and colour, choose a delivery date and address, press a button then sit back. If you want to sign a card personally, then it can be sent to your address instead and Moonpig obliges with a spare envelope for you to post it onwards.

What might have taken half an hour of messing around with a PC and printer can be done online in a few moments. Even so, Moonpig's website did lose my work in progress during one session, but after repeating the process, Moonpig's cards were successfully delivered on time and they caused quite a lot of mirth. Moonpig also offers flowers, chocolates, wines and spirits delivered through the same channel. WHSmith's **Funkypigeon.com** is an alternative card and gift website to consider, offering a much wider choice of merchandise.

Photos can be printed online the same way, and numerous photo-printing sites are available. Some of them will also import images direct from a Google Picasa or Yahoo Flickr account. The quality of results varies dramatically, and the best way of choosing the current favourite is probably to check out some comparisons in specialist photography or computer journals. In-store photo printing services are also on sale, taking images direct from your memory card and printing onto glossy photopaper. Your favourite images can also be printed onto canvas, coffee mugs, mousemats or wallposters through a variety of means, or why not design a calendar with your own photos? **Tescophoto.com** offers a range of such services (UK) and you will find many more online.

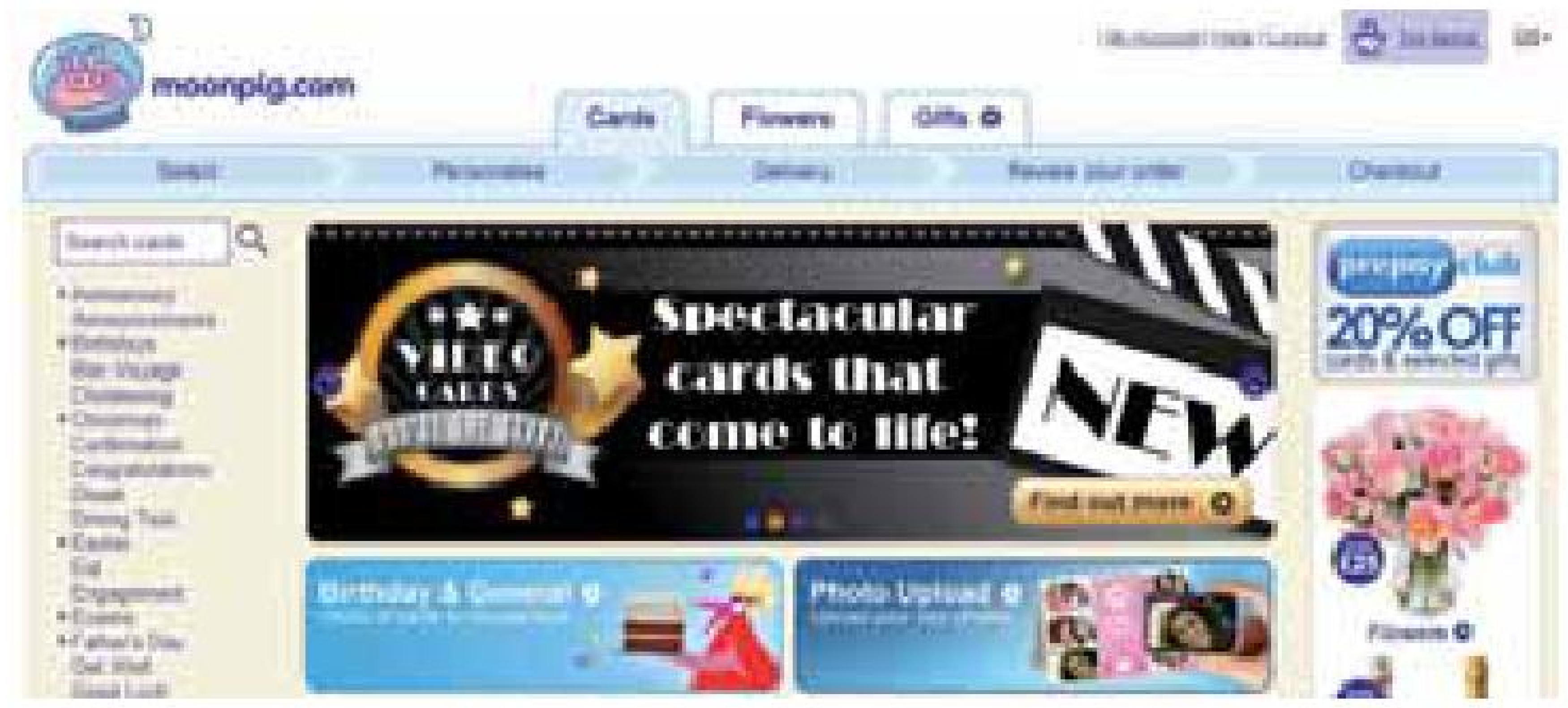
For creating personalised business cards or letter-headings over the web, Vistaprint is probably the international market leader. The costs of enhancing the quality (card thickness, number of colours, reverse-side printing) or speeding up the delivery time can soon mount up though, so beware of the initial 'teaser' pricing; Vistaprint also deletes your stored formats if you don't reorder within a set period of time. All sorts of banners, bumper stickers, window decals, rubber stamps and more are available to Internet users, and the full range can be browsed at: **www.vistaprint.co.uk/.com**

Many small businesses and groups enjoy the flexibility and choice that Vistaprint offers them, and low-cost websites are also available from £42 per year: Vistaprint upsells these bolt-on services vigorously. Other suppliers to consider in Europe and the USA include: **Goodprint.co.uk/com** and **123print.co.uk/com**. If you want something more bespoke, then in Europe consider Saxoprint (**www.saxoprint.co.uk/etc**.), who supply cards, brochures, booklets and calendars for users experienced in handling professional artwork and print. Saxoprint's online estimators are bewildering and you need to know what you're doing before committing.

Taxing times

Somewhere in my archives I have a 1977 tax return, from an era when tax computations were simple and tax returns were printed on a solitary sheet of paper. Today, a typical tax return runs to dozens of pages and the accompanying help notes will double the volume of paper sent our way. Both individuals and businesses are seeing the gradual move to submitting tax returns, VAT returns, customs and payroll data online.

Let me offer a salutary warning about taking backups of critical data, in an illustration showing how online back-ups could save the day. A business acquaintance was having severe problems using the free payroll software offered by Her Majesty's Revenue and Customs (HMRC). Their



Moonpig.com is typical of the current wave of sites that prints and posts bespoke cards.

so-called ‘Basic PAYE Tools’ software (Pay As You Earn, the UK system for gently separating income tax from our pay) is downloadable for free from: **www.hmrc.gov.uk**, and the user in question wanted to install the latest 2012/13 software on her laptop, ready for the new financial year.

For inexplicable reasons, the new year’s software would not import the employee database from the preceding period. The staff needed paying (tomorrow), but the PAYE software would not work. As I thought: some googling revealed the answer deep in an obscure forum, and it turned out that the previous year’s payroll had not been ‘closed off’ from the software’s point of view, so the new year’s payroll stubbornly refused to start.

However, this year-end closing-off task was normally performed by the firm’s accountants, who submit an annual return online themselves. With time ticking away, what could be done? What would happen if the laptop’s payroll software was ‘closed off’? Would it submit figures to HMRC online blindly and automatically? Would it conflict with the accountant’s own data? This is a typical quandary that many ordinary businesses, already overburdened by red tape, face routinely.

HMRC continues to migrate the submission of all types of returns online, and the days of the paper tax return could eventually be gone for ever. Ordinary taxpayers also face fines for failing to submit returns by the deadline, even if there’s no tax to pay, but they’re a day late saying as much.

The answer to the payroll dilemma was to let the accountants submit their own yearly figures as normal, ditch the free PAYE tools altogether and install Sage Instant Payroll on the laptop instead, which the user said was the best £100 a year they ever spent. The software registration numbers and authorisation codes soon arrived, the software was downloaded (and a CD came in the post), and, in truth, the whole Sage payroll was set up and run within an hour, evidenced by smart new payslips produced by the software. So far, so good, and the business owner was delighted!

Google Drive
Google Drive for Windows
Download Google Drive
Access Everywhere

Google Drive requires a software download to automate file syncing with the cloud

Get some back-up

At this point I explained to her the need for backups and the benefits of storing backups in the ‘cloud’. For example, Amazon offers 5GB of free Amazon Cloud storage that I’ve mentioned in previous columns. It requires an Amazon.com account (UK accounts don’t work) and as the business already had one, within 20 seconds a backup of the new payroll data was safely ensconced on Amazon’s servers. A full disk back-up had also been taken a few weeks earlier on an external pocket drive, but as I attempted to update it all sorts of odd software errors were being generated, and then (true) the laptop died in my hands!

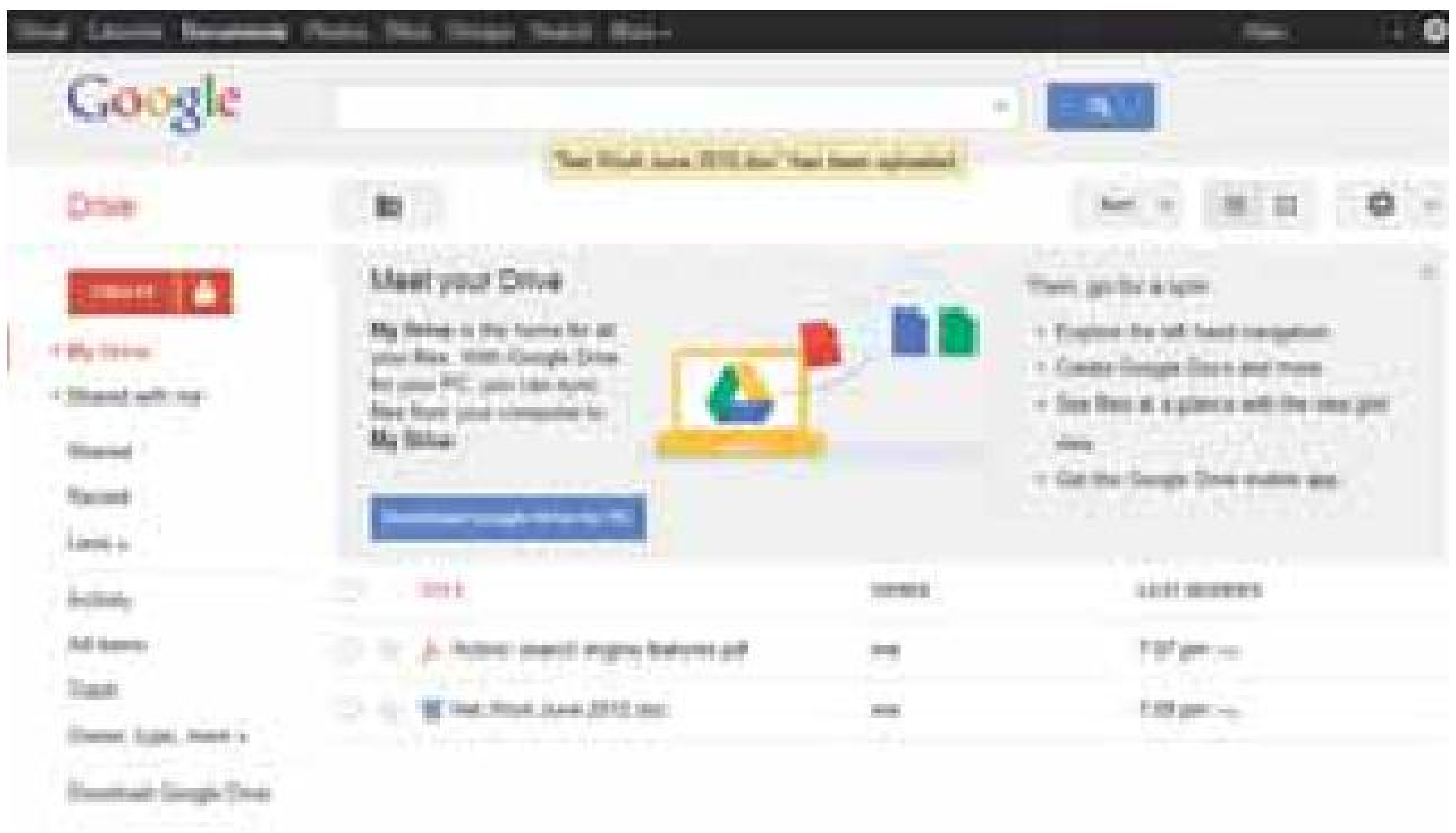
For a few days, it had been noticeable how the laptop’s fan would thrash fiercely and the laptop would become unusually hot. Then it started to lock up for no reason, and finally, the Windows XP laptop got stuck in a loop of constantly crashing and rebooting. The hard disk had indeed fried before our very eyes, taking our new Sage Payroll program with it.

A new hard drive was installed and the laptop was gradually restored. Some disk data was recovered successfully using a USB docking station. The printer driver, Microsoft Office and assorted software were installed, all kept safely in a box with their serial numbers. With Wi-Fi enabled again, we accessed Amazon Cloud instantly and restored the Sage data backup without having to start from scratch. In retrospect, I would probably keep a spreadsheet of all software registration codes on Amazon Cloud as well, but that’s a job for a rainy day.

As this true story shows, a hard disk can fail at any time, and even a dual-disk RAID system can crash, so maybe re-visit your data, digital photos, MP3s and precious files, and start planning a backup strategy on the cloud today. Buying some extra space on Amazon Cloud might be the best insurance policy you ever bought.

Google Drives your way

Google has belatedly launched its own cloud storage called Google Drive, with 5GB offered free. Google Drive is currently in beta and is compatible with Windows and Mac, Android and (soon) iPhone and iPod. While Amazon Cloud blindly hosts whatever files you upload, Google Drive can ‘OCR’ uploaded documents, PDFs or scans to make them searchable with its Google Documents framework; it will open over 30 filetypes, even if the associated software (eg, Photoshop or Adobe Reader) isn’t installed on your system.



A PDF and Word file were easily uploaded manually into GoogleDrive, simply by logging into a Google account

Instead of emailing a large file as an attachment (especially to multiple users), Google Drive lets you sync files from your computer, and a simple link can be sent in Google Mail that allows recipients to download it for themselves at a time to suit. Files can also be shared with other users and Google Drive has a 30-day rollback feature.

Internet Explorer earlier than V.9 does not support all of Google Drive’s features, which might disappoint Windows XP users, and the lack of 100% browser compatibility is becoming slightly problematic in some areas now. To use Google’s file syncing feature, software must be installed on your local PC first, which creates a Google Drive folder in My Documents.

Syncing can happen automatically, but files can also be uploaded manually by logging in with a Google account and following the prompts, as shown in the screenshots. As usual, there are too many features and sharing considerations to list, so a short period of familiarisation is necessary, but many seasoned Google Gmail account users will take to Google Drive instantly. You can make a start by visiting: **https://drive.google.com**

Other options for cloud storage include Microsoft’s SkyDrive or HiDrive from Strato (see March 2012 *Net Work*), which integrates as a folder in Windows. More and more features such as OCR and file search or syncing are gradually shifting onto the web, and the quality and usefulness of online cloud computing is increasing all the time.

You can visit the writer’s website at: **www.alanwinstanley.com** and **www.epemag.net**, or contact Alan at **alan@epemag.demon.co.uk**. You can also share your views with the editor at **editorial@wimborne.co.uk**

Check us out on the web!!

READOUT

Matt Pulzer addresses some of the general points readers have raised. Have you anything interesting to say?

Drop us a line!

WIN AN ATLAS LCR ANALYSER WORTH £7

An Atlas LCR Passive Component Analyser kindly donated by Peak Electronic Design Ltd, will be awarded to the author of the Letter Of The Month. The Atlas LCR automatically measures inductance from 1m to 10H, capacitance from 1pF to 10,000µF and resistance from 1Ω to 2MΩ with a basi accuracy of 1%. www.peakelec.co.uk

All letters quoted here have previously been replied to directly

Email: editorial@wimborne.co.u

☆ LETTER OF THE MONTH ☆

Getting to grips with Uno32

Dear editor

I read with interest Mike Hibbett's take on chipKIT (*PIC n' Mix*, *EPE*, Apr 2012). You may be interested in my recent experiences with Uno32. I have been involved with the blunt end of electronics for many years (about 40 I guess) as a career and as a hobby. Now retired, I have enjoyed the immense advances that have taken place, from the humble 7400 to the staggering power offered by modern-day microcontrollers.

One thing I struggled with is actually getting my project ideas past the prototype stage – not to say they do not work, just that the amount of time spent developing was spoiling the enjoyment of actually completing a working model and moving on with another hot project.

Green fingers

Recently, I wanted to improve a PIC-based greenhouse-watering timer. My original design had worked well, but I had in mind some improvements that would take my greenhouse automation to an almost commercial level. The plan was that my 'Remote Environment Controller' version would be split into a host controller communicating wirelessly with a slave device that monitored the temperature and possibly moisture, which also switched the heat, ventilation and watering in the greenhouse via commands from the host.

I started with a PIC16F877 host and a PIC16F624 slave, but after a few months at the workbench, and a couple of changes in processors, the project ground to a halt. At one point, I had two PICkit 2s and two MPLAB programs running simultaneously to develop and debug asm code.

However, the programming for the two parts was getting unmanageable – I was using separate 433MHz TX/RX modules that seemed problematic and required lots of control code and the like to filter out wireless fog. Program modifications took ages and eventually it all got pushed aside for another day.

chipKIT Uno32

That day came when I saw the chipKIT Uno32 advertised here in *EPE*. Rather impulsively I jumped in and sent off an order. While waiting for the postman, I was busy downloading programs and information ready for a new era, that of C++ programming (the nearest thing to Arduino).

I would be the first to say my programming skill in any language is that of a four year old, but I could make PICs work and was ready for the challenge, and the following is my experience to date.

The UNO32 is only 8cm by 7cm in size. It is based on the Arduino Uno footprint, the tech support is good and improving, and there is an active chipKIT forum to get help for problems and share ideas. My Uno32 did not work on its first test, apparently some design change made upload byte timing critical, but my request for help came quickly and a reload of the latest bootloader using PICkit 2 sorted it out.

Uno32 takes its power from the USP port or an external DC source. At its heart is an 80MHz PIC32MX320F128, a 3.3V device, but 5V is available to run additional circuits. (But do take care – not all I/O pins are 5V tolerant.)

The FTDI chip runs the serial/USB comms to the PC, and it is designed, but not exclusively, for an open source host program called MPIDE, also based on the Arduino system. Anyone considering using Uno32 should check if the PIC will match requirements; for instance, it has no embedded EEPROM area, not a great drawback as an external device can be added easily.

After setting up the USB driver and opening MPIDE on the PC, the board and port ID are selected. My first test was to load a 'sketch' called blink, which flashed the on-board LEDs successfully. My next step was to load other examples supplied with the software. After experimenting with a few code changes and lots of referring to a newly purchased thick C++ book, I felt I was ready for my own code.

In code

I really did 'throw myself in the deep end'. My design kept the remote PIC slave (now a 16F1824) as this worked and just needed some code refinements, but the controller now needed two serial ports. One for the wireless connection, and one for a u4DLCD display, an I2C link for an EEPROM, and a real-time clock chip.

The nice thing about this system is the speed at which code can be assembled, and in my case corrected, and then run. I did a lot of searching the web for code examples to copy/paste/modify into my program.

I did find the Arduino version of C++ difficult when it came to tracing errors; line numbers were not as expected, and program errors at first seemed vague. Things in 'red' were of the form '(some symbol) expected' when it was obviously there. 'Not declared in this scope' messages occurred regularly. Missing a '{' can be a disaster, but I quickly got used to keeping track of them.

Some code was straightforward. **wire.begin();** as an example, starts the I2C driver, ('wire' is a library) and very quickly I had working code for the display, EEPROM and communications to the remote PIC. There are many code libraries now available to make complex devices easier to handle; for example, SD cards, sensors and networks. But they do have obvious code size implications.

As with most code development, debugging plays an important role – with MPIDE, a serial monitor is available to keep an eye on data within the chip. Just adding simple temporary statements in code like: **serial.print(my_variable, HEX);** allows you to see if what you programmed is happening, or not!

The Uno32 has several peripherals available to the designer, and reading a post on the chipKIT forum opened up the possibility of using the PIC32MX340's RTC feature. After soldering in a 32kHz crystal it now provides a clock and alarm timer for all my host controllers functions.

I also found it helpful that some registers can be accessed by name from the code:

ALRMTIME= 0x12000000 ; // BCD format will set the RTC alarm time to 12:00.

The code also features a SET and CLEAR bit function for some registers. For example, with 433MHz the data needed to be inverted, and this can be done by adding the statement: **U2MODESET = 0x00000010 ; // invert USART2 receive data** (akin to assembler).

I was amazed how quickly 'stuff' could be put together. I knocked up a 433MHz monitor with a second Uno and a receiver in literally 10 minutes. On the negative side, the IDE editor is not that helpful and has nowhere near the features of MPLAB.

I have only scratched the surface of the Uno's power. There is also a big brother chipKIT MAX32 for more ambitious projects, which costs around £20.

I would encourage others to have a go.

Les Clarke, by email

Matt Pulzer replies:

What an inspiring letter! Thank you for taking the time to write to us and sharing your experiences with Uno32.

Soldering advice – Coldheat and tricky desoldering

Dear editor

I love the portability of the 'Coldheat' product/unit and everything in Alan Winstanley's online review article is correct (**www.epemag.wimborne.co.uk/cold-soldering.htm**), including the 'tip' fragility; however, there is no mention of a possibly better alternative.

The irony is, that it was while searching for replacement tips, that I came across your very informative article, but sadly there was no information for an alternate 'tip'. Do I have to purchase the suggested replacement part (tip) or is there a simple and hopefully better material and method I could use instead?

Both the positive and negative contacts on the coldheat unit are easily accessible and I'm not worried about damage, but I do like the units portability for the 'quick fix', and in a small town, parts for anything are really difficult to find. Any advice will be appreciated!

A Edward Moss,Kenora, ON, Canada

Alan Winstanley replies:

Thanks for your email – the now-obsolete Coldheat soldering iron was based around their so-called 'Athalite' compound, which seemed to be a resistive carbon-loaded material. The tip was split into two halves, separated by an insulator. I guess that when the tip was shorted by a conductor or solder, a short-circuit current flowed that melted the solder. The compound limited the current, while remaining cool-ish.

As I mentioned in my online review, I measured currents of several amps using fresh Duracell batteries, but in my tests the end results were never very good. I can't see any alternative to this graphite-like compound at all, unless you want to try shaping some carbon rods from a discarded 'C' cell battery or similar.

If you like the cordless portability, then I would cut your losses and buy a butane gas soldering iron. You can often get various tips, as well as a hot knife blade (for helping to finish the ends of nylon rope or seal poly bags) and a hot air blower for heatshrink – all in one unit, so you have several useful tools in one. Numerous budget versions are available on eBay, including the model similar to the Maplin-brand iron (discontinued) that I also reviewed online.

I'm sorry I could not think of an alternative, but I suspect many Coldheat iron owners now have the same problem.

Dear editor

I have just read Alan Winstanley's very thorough review of the Coldheat soldering iron. Thank you very much for your review – I was considering buying one, but now see that as a novice this one may not be right for me.

I am emailing to ask your opinion on what soldering iron would best suit me.

I recently started making jewellery and I want to know what sort of soldering iron is best for jewellery making.

Clare Smith, by email

Alan Winstanley replies:

Coldheat went out of business some time ago, and in my view the product would definitely not have been suitable for jewellery making. It had its uses (eg, on-the-spot repairs of electrical solder joints, but would have been totally uncontrollable and inconsistent in your application.

Although I'm not a jewellery maker, I do repair and resolder crystal tiaras for a friend using an electric iron. I know that small gas torches and electric soldering irons are used on the bench. I suspect that a small gas torch will give you greater flexibility, but an electric iron would be easier, more precise and cleaner to use. I would probably start with a small butane-powered gas soldering iron. These have a variety of tips and can be converted into a mini 'torch', a hot air gun or a soldering tip.

There are many choices of electric irons, including a variable temperature soldering station, say £50+, or a cheap soldering gun (100 watts) – very unwieldy, but delivering lots of heat for less than £10.

I am testing a Portasol Solder Pro gas soldering iron at the moment, which looks promising. Another reputable brand to watch for is the British-made Antex. Maplin sells a range of irons, including Iroda brands, which I also like.

For your needs, I would probably go down the gas iron approach rather than use an electric iron, as it will be more future proof and give you a bit more flexibility for working with a variety of metals. All that an electric soldering iron can do is, erm, solder!

A small book that I recommend you buy is Hot and Cold Connections *by Tim McCreight, a bench reference for jewellers.*

Alan Winstanley *EPE* online editor

Readers can contact Alan by email at: ***alan@epemag.demon.co.uk***

Appreciation of John Becker

Dear editor

I'd like to complement *EPE* for the excellent tutorial series that you have published over the years. My 'techy' colleagues and I owe a debt of gratitude to John Becker (now sadly departed) for his well-crafted tutorials on PIC development. Some of John's original interfacing routines are still serving us well; the two- and four-line LCD character display interface being a fine example of John's work.

We have recently become interested in the emergence of the Raspberry Pi, although details and availability are somewhat restricted at present. It seems to be aimed at the education sector, where the on-board media interfaces and simplicity of the Python language offer a quick introduction to programming techniques.

Last, a little (hopefully) constructive criticism – is *EPE* is in danger of becoming over-populated with Aussie 'petrol head' engine management gizmos (courtesy of *Silicon Chip*)? I know it is difficult to please everyone, but without doubt, John Becker's skill was that he was able to write well-structured material that inspired professionals, hobbyists and students to develop their own projects – more inspiration, please!

Pete Barrett, , by email

Matt Pulzer replies:

Hi Pete – It's great to hear that John's designs live on, I'm sure it would please him greatly to know his hard work and dedication to EPE is still appreciated. We are monitoring Raspberry Pi's progress and I'm sure we will soon be covering it in EPE.

Yes, it is difficult to please everyone, all of the time. Auto projects are very popular, but you can have too much of a good thing, so while we will have more, perhaps not so many

IF YOU HAVE A SUBJECT YOU WISH TO DISCUSS IN READOUT PLEASE EMAIL US AT:

editorial@wimborne.co.uk

Max’s Cool Beans

By Max The Magnificent

As you may recall from my previous columns, it was quite some time before I decided to purchase an iPad.

In fact, I really didn’t become interested until I went to an electronics conference in the summer of 2011. It seemed like everyone I knew out there had iPads and were using them to capture notes and ‘stuff’. This was further rubbed home on the flight back, when my cramped seat meant that I couldn’t use my notepad computer, but the person next to me was happily typing away on his iPad. Thus, the next day, I raced down to my local Apple store and purchased a 64GB WiFi iPad 2 ... and I've never looked back.

A touch of style

When I first purchased my iPad, I also bought one of Apple's Smart Covers for it (**www.apple.com/ipad/smartcover**). On the one hand this cover is really convenient, because it attaches to the iPad using super-strong magnets, it's really thin, it can be folded into a stand, and it automatically activates/deactivates the iPad when you pull it open/closed.

But then I ran across a company called Saddleback Leather (**www.saddlebackleather.com**), which offers the most amazing leather goods. These products are made out of 1/8-inch thick, super-high-quality leather, and each product comes with a 100 year guarantee (seriously)! I currently own a 1.75-inch wide Tow Belt, a cover for my iPad, and a Messenger Bag.

All of these products will last me for the rest of my life. But we digress, suffice it to say that I love my leather iPad case and I wouldn’t trade it for the world.

Apple TV

In addition to all of its other functions, I use my iPad to watch television programmes. This may seem strange, but I prefer to watch a series in order, and when I'm in the flow I like to watch the programmes when I want to watch them. The problem is that my wife usually wants to watch one thing and my son wants to watch something else. We could all go off into different rooms, but that's not really what life is all about. The solution (for me) is to download a series like *The Big Bang Theory* to my iPad, and then watch the episodes at my leisure.

Now this is where I have to admit to feeling a little foolish, because I’ve heard the term Apple TV being bandied around in conversation, but I never really knew what one was. For some reason, I guess, I assumed that this referred to a digital TV that was in some way ‘Apple-compliant’ or ‘Apple-friendly’.

You are probably aware that I was completely wrong. As I have now discovered, the term Apple TV actually refers to a rinky-dinky little box around 4-inches square and one inch deep that sits next to your regular digital TV and connects to it via an HDMI cable. The Apple TV also connects to your wireless router, thereby allowing you to stream content from the Internet and/or from your iPad or whatever.

This is great. Whenever I'm on my own, I can wirelessly stream my videos from my iPad to my Apple TV and watch my programmes on the high-definition television in my family room. Furthermore, if we have family round and I want to show them pictures from something like my recent trip to Norway, I can simply ‘mirror’ my iPad with the Apple TV, so anything that appears on my iPad screen also appears much larger on the main TV.

Wireless Boombox

Speaking of ‘wireless’ ... I just love the way you can get all of your gadgets to ‘talk’ to each other without having to connect cables (I remember the old ‘entertainment systems,’ whose main entertainment value came from watching some poor soul trying to work out where all the wires went).

The thing is, I was enjoying a lazy Saturday afternoon sitting on our back deck, reading an e-book on my iPad, and sort of letting my mind wander. For some reason I started to think about a Supertramp concert I had seen back in late 1970s. This gave me an urge to listen to some Supertramp, so I immediately (and wirelessly) downloaded a couple of albums from the iTunes store.

The thing was, you can only get so much sound out of an iPad, and I quickly grew to want more! So I searched the web (using my iPad, of course) for wireless speakers. There are lots of different options available, from docking stations to multiple stand-alone units. The one I ended up really liking the look of was the Logitech Wireless Boombox for iPad, iPhone and iPod touch, which I found on **Amazon.com**.

This little beauty connects to your iPad (or iPhone or whatever) via Bluetooth. With dimensions of 18.8-inches long, 5.5-inches tall, and 3.7-inches deep, it’s a pretty beefy unit. You can get smaller units, but this is just what I wanted. The base sounds ‘meaty’, the mid-range is where you would expect it to be, and the treble is well represented without being ‘squeaky’. The world truly is my lobster (or any crustacean of your choice).

Until next time, have a good one!

DIRECT BOOK SERVICE

ELECTRONICS TEACH-IN BUNDLE – SPECIAL BUNDLE PRICE £14 FOR PARTS 1, 2 & 3

ELECTRONICS TEACH-IN 2 CD-ROM USING PIC MICROCONTROLLERS A PRACTICAL INTRODUCTION

This *Teach-In* series of articles was originally published in *EPE* in 2008 and, following demand from readers, has now been collected together in the *Electronics Teach-In 2* CD-ROM.

The series is aimed at those using PIC microcontrollers for the first time. Each part of the series includes breadboard layouts to aid understanding and a simple programmer project is provided.

Also included are 29 *PIC N' Mix* articles, also republished from *EPE*. These provide a host of practical programming and interfacing information, mainly for those that have already got to grips with using PIC microcontrollers. An extra four part beginners guide to using the C programing language for PIC microcontrollers is also included.

The CD-ROM also contains all of the software for the *Teach-In 2* series and *PIC N' Mix* articles, plus a range of items from Microchip – the manufacturers of the PIC microcontrollers. The material has been compiled by Wimborne Publishing Ltd. with the assistance of Microchip Technology Inc.

The Microchip items are: MPLAB Integrated Development Environment V8.20; Microchip Advance Parts Selector V2.32; Treelink; Motor Control Solutions; 16-bit Embedded Solutions; 16-bit Tool Solutions; Human Interface Solutions; 8-bit PIC Microcontrollers; PIC24 Micrcontrollers; PIC32 Microcontroller Family with USB On-The-Go; dsPIC Digital Signal Controllers.

CD-ROM **Order code ETI2 CD-ROM** £9.50

FREE CD-ROM

ELECTRONICS TEACH-IN 3

The three sections of this book cover a very wide range of subjects that will interest everyone involved in electronics, from hobbyists and students to professionals. The first 80-odd pages of Teach-In 3 are dedicated to *Circuit Surgery*, the regular *EPE* clinic dealing with readers' queries on various circuit design and application problems – everything from voltage regulation to using SPICE circuit simulation software.

The second section – *Practically Speaking* – covers the practical aspects of electronics construction. Again, a whole range of subjects, from soldering to avoiding problems with static electricity and indentifying components, are covered. Finally, our collection of *Ingenuity Unlimited* circuits provides over 40 circuit designs submitted by the readers of *EPE*.

The free cover-mounted CD-ROM is the complete *Electronics Teach-In 1* book, which provides a broad-based introduction to electronics in PDF form, plus interactive quizzes to test your knowledge, TINA circuit simulation software (a limited version – plus a specially written TINA Tutorial), together with simulations of the circuits in the Teach-In 1 series, plus Flowcode (a limited version) a high level programming system for PIC microcontrollers based on flowcharts.

The Teach-In 1 series covers everything from Electric Current through to Microprocessors and Microcontrollers and each part includes demonstration circuits to build on breadboards or to simulate on your PC. There is also a MW/LW Radio project in the series. The contents of the book and Free CD-ROM have been reprinted from past issues of *EPE*.

160 pages **Order code ETI3** £8.50

Book and CD-ROMs Bundle Price **£14.00**

NEW

ELECTRONICS TEACH-IN 4

FREE CD-ROM

ELECTRONICS TEACH-IN 4

A Broad-Based Introduction to
Electronics plus FREE CD-ROM

The Teach-In 4 book covers three of the most important electronics units that are currently studied in many schools and colleges. These include, Edexcel BTEC level 2 awards and the electronics units of the new Diploma in Engineering, Level 2.

The Free cover-mounted CD-ROM contains the full Modern Electronics Manual, worth £29.95. The Manual contains over 800 pages of electronics theory, projects, data, assembly instructions and web links.

A package of exceptional value that will appeal to all those interested in learning about electronics or brushing up on their theory, be they hobbyists, students or professionals.

144 pages **Order code ETI4** £8.99

RADIO

AN INTRODUCTION TO RADIO WAVE PROPOGATION

J.G. Lee

Radio wave propogation is one of the more important discoveries made in the early 20th century. Although technology lagged behind early experimenters pursued this newly discovered phenomenon eagerly for, in understanding the physics of propagation, they were discovering more about our Universe and its workings.

Radio wave propagation has its origins in the world of solar physics. The Sun's radiation provides the mechanism for the formation of the ionosphere. How the ionosphere is formed, and how it provides long-distance communication, is carefully explained. Non-ionospheric propagation, including 'moonbounce' or satellite communications, is covered as well.

This book has been written with the average electronic hobbyist in mind. Technical language and mathematics have been kept to a minimum in order to present a broad, yet clear, picture of the subject. The radio amateur, as well as the short-wave listener, will find explanations of the propogation phenomena which both experience in their pursuit of communications enjoyment.

116 pages **Order code BP293** £4.45

PROJECT CONSTRUCTION

IC 555 PROJECTS

E. A. Parr

Every so often a device appears that is so useful that one wonders how life went on before without it. The 555 timer is such a device. Included in this book are over 70 circuit diagrams and descriptions covering basic and general circuits, motor car and model railway circuits, alarms and noise makers as well as a section on 556, 558 and 559 timers. (Note. No construction details are given.) A reference book of invaluable use to all those who have any interest in electronics, be they professional engineers or designers, students or hobbyists.

167 pages **Order code BP44** £5.49

HOW TO USE OSCILLOSCOPES AND OTHER TEST EQUIPMENT

R. A. Penfold

This book explains the basic function of an oscilloscope, gives a detailed explanation of all the standard controls, and provides advice on buying. A separate chapter deals with using an oscilloscope for fault finding on linear and logic circuits, plenty of example waveforms help to illustrate the control functions and the effects of various fault conditions. The function and use of various other pieces of test equipment are also covered, including signal generators, logic probes, logic pulsers and crystal calibrators.

104 pages **Order code BP267** £5.49

ELECTRONIC PROJECT BUILDING FOR BEGINNERS

R. A. Penfold

This book is for complete beginners to electronic project building. It provides a complete introduction to the practical side of this fascinating hobby, including the following topics:

Component identification, and buying the right parts; resistor colour codes, capacitor value markings, etc; advice on buying the right tools for the job; soldering; making easy work of the hard wiring; construction methods, including stripboard, custom printed circuit boards, plain matrix boards, surface mount boards and wire-wrapping; finishing off, and adding panel labels; getting "problem" projects to work, including simple methods of fault-finding.

In fact everything you need to know in order to get started in this absorbing and creative hobby.

135 pages **Order code BP392** £5.99

The books listed have been selected by *Everyday Practical Electronics* editorial staff as being of special interest to everyone involved in electronics and computing. They are supplied by mail order direct to your door. Full ordering details are given on the last book page.

FOR A FURTHER SELECTION OF BOOKS AND CD-ROMS SEE THE UK SHOP ON OUR WEBSITE – www.epemag.com

All prices include UK postage
1

COMPUTING

NEW

FREE DOWNLOADS TO PEP-UP AND PROTECT YOUR PC

R. A. Penfold

Bob Penfold, uses his vast knowledge and experience in computing to guide you simply through the process of finding reliable sites and sources of free software that will help optimize the performance and protect your computer against most types of malicious attack.

Among the many topics covered are: Using Windows 7 optimization wizard; PCPitstop for advice on improving performance, reducing start up times, etc; Free optimization scans and the possibility of these being used as a ploy to attack your PC; Free programs such as Ccleaner, Registry checker and PCPal optimization software; Internet speed testing sites and download managers; Overclocking sites, together with warnings about using this technique; Sites and software for diagnosis of hardware faults, including scanning for out of date drivers and finding suitable replacements; Free Antivirus software and programs that combat specific types of malware; Firewalls; Search engines to identify mystery processes listed in Windows Task Manager.

128 pages **Order code BP722** £7.99

COMPUTING FOR THE OLDER GENERATION

Jim Gatenby

Among the many practical and useful ideas for using your PC that are covered in this book are: Choosing, setting up and understanding your computer and its main components. Writing letters, leaflets, invitations, etc., and other word processing jobs. Keeping track of your finances using a spreadsheet. Recording details of holidays and other ideas using a database. Using the Internet to find useful information, and email to keep in touch with family and friends. Making 'back-up' copies of your work and checking for viruses. How to use Windows XP to help people with impaired vision, hearing or mobility.

308 pages **Order code BP601** £8.99

FOR MORE BOOKS & CD-ROMS CHECK OUT www.epemag.com

THEORY AND REFERENCE

BEBOP TO THE BOOLEAN BOOGIE
Second Edition
Clive (call me Max) Maxfield

This book gives the "big picture" of digital electronics. This in-depth, highly readable, guide shows you how electronic devices work and how they're made. You'll discover how transistors operate, how printed circuit boards are fabricated, and what the innards of memory ICs look like. You'll also gain a working knowledge of Boolean Algebra and Karnaugh Maps, and understand what Reed-Muller logic is and how it's used. And there's much, MUCH more. The author's tongue-in-cheek humour makes it a delight to read, but this is a REAL technical book, extremely detailed and accurate.

Contents: Fundamental concepts; Analog versus digital; Conductors and insulators; Voltage, current, resistance, capacitance and inductance; Semiconductors; Primitive logic functions; Binary arithmetic; Boolean algebra; Karnaugh maps; State diagrams, tables and machines; Analog-to-digital and digital-to-analog; Integrated circuits (ICs); Memory ICs; Programmable ICs; Application-specific integrated circuits (ASICs); Circuit boards (PWBs and DWBs); Hybrids; Multichip modules (MCMs); Alternative and future technologies.

470 pages **Order code BEB1** **£35.99**

BEBOP BYTES BACK (and the Beboputer Computer Simulator) CD-ROM
Clive (Max) Maxfield
and Alvin Brown

CD-ROM

This follow-on to Bebop to the Boolean Boogie is a multimedia extravaganza of information about how computers work. It picks up where "Bebop I" left off, guiding you through the fascinating world of computer design . . . and you'll have a few chuckles, if not belly laughs, along the way. In addition to over 200 megabytes of mega-cool multimedia, the CD-ROM contains a virtual microcomputer, simulating the motherboard and standard computer peripherals in an extremely realistic manner. In addition to a wealth of technical information, myriad nuggets of trivia, and hundreds of carefully drawn illustrations, the CD-ROM contains a set of lab experiments for the virtual microcomputer that let you recreate the experiences of early computer pioneers. If you're the slightest bit interested in the inner workings of computers, then don't dare to miss this!

Over 800 pages in Adobe Acrobat format

CD-ROM **Order code BEB2 CD-ROM** **£21.95**

BEBOP
Boolean Boogie
Ian Sinclair
Practical Electronics Handbook
FIFTH EDITION

INTERFACING PIC MICROCONTROLLERS
Martin Bates

An essential guide to PIC interfacing techniques, using circuit simulation to aid learning.

Explore in detail microcontroller interfacing techniques using the popular PIC 16F877. Work through step-by-step examples interactively using circuit simulation software, supplied as assembly source code.

Interfacing PIC Microcontrollers provides a thorough introduction to interfacing techniques for students, hobbyists and engineers looking to take their knowledge of PIC application development to the next level. Each chapter ends with suggestions for further applications, based on the examples given, and numerous line drawings illustrate application of the hardware.

Step-by-step examples in assembly language are used to illustrate a comprehensive set of interfaces, and these can be run interactively on circuit simulation software, used to aid understanding without the need to build real hardware.

A companion website includes all examples in the text which cam be downloaded together with a free version of Proteus's ISIS Lite.

298 pages **Order code NE48** **£30.99**

GETTING THE MOST FROM YOUR MULTIMETER
R. A. Penfold

This book is primarily aimed at beginners and those of limited experience of electronics. Chapter 1 covers the basics of analogue and digital multimeters, discussing the relative merits and the limitations of the two types. In Chapter 2 various methods of component checking are described, including tests for transistors, thyristors, resistors, capacitors and diodes. Circuit testing is covered in Chapter 3, with subjects such as voltage, current and continuity checks being discussed.

In the main little or no previous knowledge or experience is assumed. Using these simple component and circuit testing techniques the reader should be able to confidently tackle servicing of most electronic projects.

102 pages **Order code BP239** **£5.49**

OPERATIONAL AMPLIFIER USER'S HANDBOOK
R. A. Penfold

The first part of this book covers standard operational amplifer based "building blocks" (integrator, precision rectifier, function generator, amplifiers, etc), and considers the ways in which modern devices can be used to give superior performance in each one. The second part describes a number of practical circuits that exploit modern operational amplifiers, such as high slew-rate, ultra low noise, and low input offset devices. The projects include: Low noise tape preamplifier, low noise RIAA preamplifier, audio power amplifiers, d.c. power controllers, opto-isolator audio link, audio millivolt meter, temperature monitor, low distortion audio signalgenerator, simple video fader, and many more.

120 pages **Order code BP335** **£5.45**

PRACTICAL ELECTRONICS HANDBOOK – Fifth Edition. Ian Sinclair

Provides a practical and comprehensive collection of circuits, rules of thumb and design data for professional engineers, students and enthusaists, and therefore enough background to allow the understanding and development of a range of basic circuits.

Contents: Passive components, Active discrete components, Circuits, Linear I.C.s, Energy conversion components, Digital I.C.s, Microprocessors and microprocessor systems, Transferring digital data, Digital-analogue conversions, Computer aids in electronics, Hardware components and practical work, Micro-controllers and PLCs, Digital broadcasting, Electronic security.

440 pages **Order code NE21** **£32.50**

FOR MORE BOOKS
& CD-ROMS
CHECK OUT
www.epemag.com

MUSIC, AUDIO AND VIDEO

QUICK GUIDE TO DIGITAL AUDIO RECORDING
Ian Waugh

Covers:
- What computer system you need
- Sound and digital audio essentials
- What to look for in a sound card
- What effects to use
- The art of mixing
- How to burn your music to CD
- How to post your songs on the Web

All modern music recordings use digital audio technology. Now everyone with a compouter can produce CD-quality recordings and this book shows you how. Written in a clear and straightforward style, it explains what digital audio recording is, how to use it, the equipment you need, what sort of software is available and how to achieve professional results.

Computer-based recording is the future of music and this book shows how you can join the revolution now.

208 pages **Order code PC121** **£7.95**

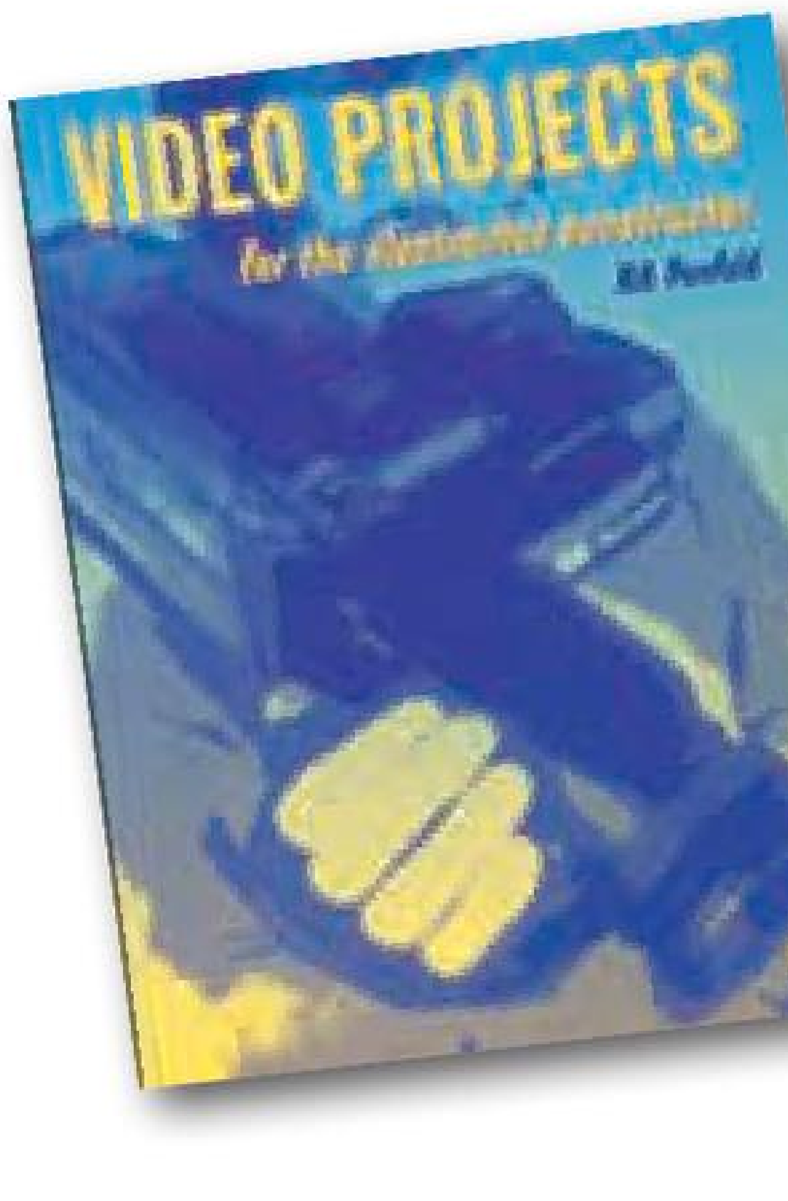
QUICK GUIDE TO MP3 AND DIGITAL MUSIC
Ian Waugh

MP3 files, the latest digital music format, have taken the music industry by storm. What are they? Where do you get them? How do you use them? Why have they thrown record companies into a panic? Will they make music easier to buy? And cheaper? Is this the future of music?

All these questions and more are answered in this concise and practical book which explains everything you need to know about MP3s in a simple and easy-to-understand manner. It explains:

How to play MP3s on your computer; How to use MP3s with handheld MP3 players; Where to find MP3s on the Web; How MP3s work; How to tune into Internet radio stations; How to create your own MP3s; How to record your own CDs from MP3 files; Other digital audio music formats.

Temporarily out of print



ELECTRONIC PROJECTS FOR VIDEO ENTHUSIASTS
R. A. Penfold

This book provides a number of practical designs for video accessories that will help you get the best results from your camcorder and VCR. All the projects use inexpensive components that are readily available, and they are easy to construct. Full construction details are provided, including stripboard layouts and wiring diagrams. Where appropriate, simple setting up procedures are described in detail; no test equipment is needed.

The projects covered in this book include: Four channel audio mixer, Four channel stereo mixer, Dynamic noise limiter (DNL), Automatic audio fader, Video faders, Video wipers, Video crispener, Mains power supply unit.

109 pages **Order code BP356** **£5.45**

MAKING MUSIC WITH YOUR COMPUTER
Stephen Bennett

Nearly everyone with musical aspirations also has a computer. This same computer can double as a high quality recording studio capable of producing professional recordings. This book tells you what software and hardware you will need to get the best results.

You'll learn about recording techniques, software and effects, mixing, mastering and CD production.

Suitable for PC and Mac users, the book is full of tips, "how to do" topics and illustrations. It's the perfect answer to the question "How do I use my computer to produce my own CD?"

92 pages **Order code PC120** **£10.95**

ALL PRICES INCLUDE UK POST & PACKING

FAULT FINDING, CIRCUITS AND DESIGN

STARTING ELECTRONICS – 4th Edition
Keith Brindley

A Starting Electronics is unrivalled as a highly practical introduction for technicians, non-electronic engineers, software engineers, students, and hobbyists. Keith Brindley introduces readers to the functions of the main component types, their uses, and the basic principles of building and designing electronic circuits. Breadboard layouts make this very much a ready-to-run book for the experimenter, and the use of readily available, inexpensive components makes this practical exploration of electronics easily accessible to all levels of engineer and hobbyist.

Other books tell readers what to do, but sometimes fail to explain why – Brindley gives readers hands-on confidence in addition to real scientific knowledge, and insight into the principles as well as the practice. All written explanations and steps are supplemented with numerous photos, charts, tables and graphs. Concepts and practical aspects are explained thoroughly with mathematical formulae and technical schematic drawings.

Each chapter introduces a concept or tool, explains the basic theory, and provides clear instructions for a simple experiment to apply the concept or tool, with quiz sections and answers, at the end of each chapter.

296 pages **Order code NE100** **£18.99**

HOW ELECTRONIC THINGS WORK – AND WHAT TO DO WHEN THEY DON'T
Robert Goodman

You never again have to be flummoxed, flustered or taken for a ride by a piece of electronics equipment. With this fully illustrated, simple-to-use guide, you will get a grasp on the workings of the electronic world that surrounds you – and even learn to make your own repairs.

You don't need any technical experience. This book gives you: Clear explanations of how things work, written in everyday language. Easy-to-follow, illustrated instructions on using test equipment to diagnose problems. Guidelines to help you decide for or against professional repair. Tips on protecting your expensive equipment from lightning and other electrical damage, lubrication and maintenance suggestions.

Covers: colour TVs, VCRs, radios, PCs, CD players, printers, telephones, monitors, camcorders, satellite dishes, and much more!

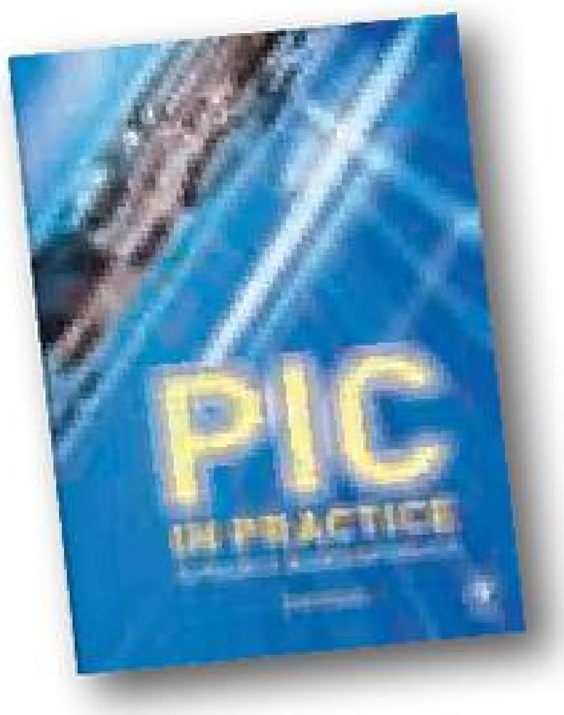
394 pages **Order code MGH3** **£21.99**

PIC IN PRACTICE (2nd Edition)
David W. Smith

A graded course based around the practical use of the PIC microcontroller through project work. Principles are introduced gradually, through hands-on experience, enabling hobbyists and students to develop their understanding at their own pace. The book can be used at a variety of levels.

Contents: Introduction to the PIC microcontroller; Programming the 16F84 microcontroller; Introductory projects; Headers, porting code – which micro?; Using inputs; Keypad scanning; Program examples; The 16C54 microcontroller; Alphanumeric displays; Analogue to digital conversion; Radio transmitters and receivers; EEPROM data memory; Interrupts; The 12 series 8-pin microcontroller; The 16F87X microcontroller; The 16F62X microcontroller; Projects; Instruction set, files and registers; Appendices; Index.

308 pages **Order code NE39** **£24.99**



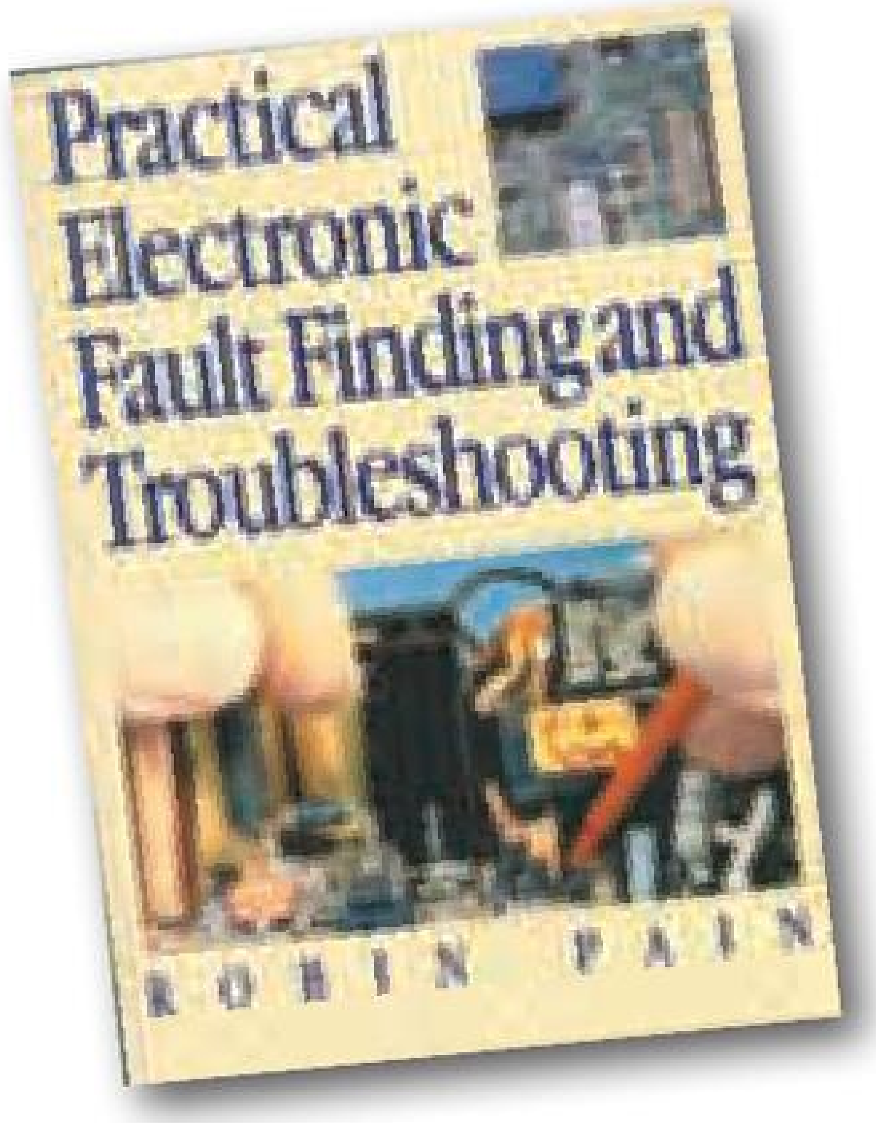
PRACTICAL ELECTRONIC FAULT FINDING AND TROUBLESHOOTING
Robin Pain

To be a real fault finder, you must be able to get a feel for what is going on in the circuit you are examining. In this book Robin Pain explains the basic techniques needed to be a fault finder.

Simple circuit examples are used to illustrate principles and concepts fundamental to the process of fault finding. This is not a book of theory, it is a book of practical tips, hints and rules of thumb, all of which will equip the reader to tackle any job. You may be an engineer or technician in search of information and guidance, a college student, a hobbyist building a project from a magazine, or simply a keen self-taught amateur who is interested in electronic fault finding but finds books on the subject too mathematical or specialised.

The fundamental principles of analogue and digital fault finding are described (although, of course, there is no such thing as a "digital fault" – all faults are by nature analogue). This book is written entirely for a fault finder using only the basic fault-finding equipment: a digital multimeter and an oscilloscope. The treatment is non-mathematical (apart from Ohm's law) and all jargon is strictly avoided.

274 pages **Order code NE22** **£41.99**



AUDIO AMPS

BUILDING VALVE AMPLIFIERS
Morgan Jones

The practical guide to building, modifying, fault-finding and repairing valve amplifiers. A hands-on approach to valve electronics – classic and modern – with a minimum of theory. Planning, fault-finding, and testing are each illustrated by step-by-step examples.

A unique hands-on guide for anyone working with valve (tube in USA) audio equipment – as an electronics experimenter, audiophile or audio engineer.

Particular attention has been paid to answering questions commonly asked by newcomers to the world of the vacuum tube, whether audio enthusiasts tackling their first build, or more experienced amplifier designers seeking to learn the ropes of working with valves. The practical side of this book is reinforced by numerous clear illustrations throughout.

368 pages **Order code NE40** **£29.00**

VALVE AMPLIFIERS
Second Edition. Morgan Jones

This book allows those with a limited knowledge of the field to understand both the theory and practice of valve audio amplifier design, such that they can analyse and modify circuits, and build or restore an amplifier. Design principles and construction techniques are provided so readers can devise and build from scratch, designs that actually work.

The second edition of this popular book builds on its main strength – exploring and illustrating theory with practical applications. Numerous new sections include: output transformer problems; heater regulators; phase splitter analysis; and component technology. In addition to the numerous amplifier and preamplifier circuits, three major new designs are included: a low-noise single-ended LP stage, and a pair of high voltage amplifiers for driving electrostatic transducers directly – one for headphones, one for loudspeakers.

288 pages **Order code NE33** **£40.99**

BOOK ORDER FORM

Full name: ....

Address: ....

....

....

.... Post code: .... Telephone No: ....

Signature: ....

☐ I enclose cheque/PO payable to DIRECT BOOK SERVICE for £ ....

☐ Please charge my card £ .... Card expiry date..

Card Number .... Maestro Issue No.............................

Valid From Date .... Card Security Code .... (the last three digits on or just below the signature strip)

Please send book order codes: ....

....

Please continue on separate sheet of paper if necessary

BOOK ORDERING DETAILS

All prices include UK postage. For postage to Europe (air) and the rest of the world (surface) please add £3 per book. For the rest of the world airmail add £4 per book. CD-ROM prices include VAT and/or postage to anywhere in the world. Send a PO, cheque, international money order (£ sterling only) made payable to **Direct Book Service** or card details, Visa, Mastercard, or Maestro to: **DIRECT BOOK SERVICE, WIMBORNE PUBLISHING LIMITED, 113 LYNWOOD DRIVE, MERLEY, WIMBORNE, DORSET BH21 1UU.**

Books are normally sent within seven days of receipt of order, but please allow 28 days for delivery – more for overseas orders. *Please check price and availability (see latest issue of* Everyday Practical Electronics*) before ordering from old lists.*

For a further selection of books see the next two issues of *EPE*.
Tel 01202 880299 Fax 01202 843233. E-mail: dbs@wimborne.co.uk
Order from our online UK shop at: www.epemag.com

PCB SERVICE

CHECK US OUT ON THE WEB

Printed circuit boards for most recent *EPE* constructional projects are available from the *PCB Service*, see list. These are fabricated in glass fibre, and are fully drilled and roller tinned. Double-sided boards are **NOT plated through hole** and will require 'vias' and some components soldering to both sides. All prices include VAT and postage and packing. Add £2 per board for airmail outside of Europe. Remittances should be sent to **The PCB Service, Everyday Practical Electronics, Wimborne Publishing Ltd., 113 Lynwood Drive, Merley, Wimborne, Dorset BH21 1UU. Tel: 01202 880299; Fax 01202 843233; Email: orders@epemag.wimborne.co.uk. On-line Shop: www.epemag.com**. Cheques should be crossed and made payable to *Everyday Practical Electronics* **(Payment in £ sterling only)**.

NOTE: While 95% of our boards are held in stock and are dispatched within seven days of receipt of order, please allow a maximum of 28 days for delivery – overseas readers allow extra if ordered by surface mail. Back numbers or photocopies of articles are available if required – see the Back Issues page for details. WE DO NOT SUPPLY KITS OR COMPONENTS FOR OUR PROJECTS.

Please check price and availability in the latest issue. A large number of older boards are listed on, and can be ordered from, our website.

Boards can only be supplied on a payment with order basis.

PROJECT TITLE	ORDER CODE	COST
MAY '11		
★6-Digit GPS Clock	800	£12.83
Simple Voltage Switch For Car Sensors	801	£8.16
The μCurrent (double-sided, surface mount)	802	£13.80
★Digital Audio Oscillator (double-sided)	803	£14.20
JUNE '11		
230V AC 10A Full-Wave Motor Speed Controller	804	£10.69
Precision 10V DC Voltage Reference	805	£7.77
6-Digit GPS Clock Driver (Pt.2)	806	£8.16
Musicolour IRDA Accessory	807	£7.38
JULY '11		
Beam-Break Flash Trigger – IR Source	808	pair £9.72
– Detector	809	
Metal Locator	810	£8.56
Multi-Function Active Filter	812	£10.00
Active AM Loop Antenna and Amp (inc. Varicaps)		
– Antenna/Amp	813	pair £10.67
– Radio Loop	814	
AUGUST '11		
Input Attenuator for the Digital Audio Millvoltmeter	811	£7.58
★SD Card Music & Speech Recorder/Player	815	£13.61
★Deluxe 3-Chan. UHF Rolling Code Remote Control – Transmitter	816	pair £12.43
– Receiver	817	
SEPTEMBER '11		
★ Digital Megohm and Leakage Current Meter	818	£9.72
Auto-Dim for 6-Digit GPS Clock	819	£6.80
OCTOBER '11		
★ High-Quality Stereo DAC –		
Input & Control Board	820	set £20.41
Stereo DAC/Analogue Board	821	
Front Panel Switch	822	
Power Supply Board	823	
Twin Engine SpeedMatch Indicator	824	£8.75
★ Wideband Air/Fuel Display (double-sided)	825	£14.38
NOVEMBER '11		
★ Digital Capacitor Leakage Meter	826	£10.11
One-of-Nine Switch Indicator		
– Main Board	827	pair £11.27
– Remote Display Board	828	
DECEMBER '11		
★ Wideband Oxygen Sensor Controller	829	£11.47
★ WIB (Web Server In A Box)	830	£9.72
★ Ginormous 7-segment LED Panel Meter		
– Master (KTA-255v2)	831	£12.67
– Slave (KTA-256v2)	832	£5.05
– Programmed Atmega328		£10.13
JANUARY '12		
Balanced Output Board For The Stereo DAC	833	£9.72
FEBRUARY '12		
★ Air Quality Monitor (CO_2/CO)	834	£8.75
WIB Connector Daughter PCB	835	£6.80
MARCH '12		
★ Internet Time Display Module	836	£8.16
Solar-Powered Intruder Alarm	837	£9.33
★ Very, Very Accurate Thermometer/Thermostat	840	£9.33
APRIL '12		
★ Digital Audio Signal Generator		
– Main Board (Jay *or* Alt)	838	pair £18.86
– Control/Display Board	839	
EHT Stick	841	£9.15
Capacitor Leakage Adaptor For DMMs	842	£9.72
MAY '12		
High-Performance 12V Stereo Amplifier	843	£9.14
Low-Power Car/Bike USB Charger	844	£7.58
★ Solar-Powered Lighting Controller	845	£9.91
Jump Start – Plant Pot Moisture Sensor	846	£7.97
– Rain Alarm (Main)	847	pair £15.36
– Rain Alarm (Sensor)	848	
JUNE '12		
★ Digital Insulation Meter		
– Main/Display	849	pair £16.33
– DC-DC Converter	850	
Dual Tracking ±0V to 19V PSU		
– Main PCB	851	£9.33
– Front Panel	852	£8.16
– LCD Meter	853	£7.19
Jump Start Quiz Machine		
– Master	854	£7.39
– Contestant	855	£7.39
JULY '12		
★ 16-Bit Digital Potentiometer	856	£13.99
★ Intelligent 12V Fan Controller	857	£10.10
Jump Start – Battery Voltage Checker	858	£9.14

EPE SOFTWARE

★ All software programs for *EPE* Projects marked with a star, and others previously published can be downloaded free from the Library on our website, accessible via our home page at: **www.epemag.com**

PCB MASTERS

PCB masters for boards published from the March '06 issue onwards can also be downloaded from our website (**www.epemag.com**); **go to the 'Library' section.**

EPE PRINTED CIRCUIT BOARD SERVICE

Order Code **Project** **Quantity** **Price**

. . . .

Name . . . .

Address . . . .

. . . .

Tel. No. . . . .

I enclose payment of £ . . . . (cheque/PO in **£ sterling only**) to:

Everyday Practical Electronics

Card No. . . . .

Valid From . . . . Expiry Date . . . .

Card Security No. . . . . Maestro Issue No. . . . . . .

Signature . . . .

Note: You can also order PCBs by phone, Fax or Email or via the Shop on our website on a secure server:

http://www.epemag.com

CLASSIFIED
ADVERTISEMENTS

Everyday Practical Electronics reaches more UK readers than any other UK monthly hobby electronics magazine, our sales figures prove it. We have been the leading monthly magazine in this market for the last twenty-five years.

If you want your advertisements to be seen by the largest readership at the most economical price our classified page offers excellent value. The rate for semi-display space is £10 (+VAT) per centimetre high, with a minimum height of 2·5cm. All semi-display adverts have a width of 5.5cm. The prepaid rate for classified adverts is 40p (+VAT) per word (minimum 12 words).
All cheques, postal orders, etc., to be made payable to Everyday Practical Electronics. **VAT must be added**. Advertisements, together with remittance, should be sent to Everyday Practical Electronics Advertisements, 113 Lynwood Drive, Merley, Wimborne, Dorset, BH21 1UU. Phone: 01202 880299. Fax: 01202 843233. Email: stewart.kearn@wimborne.co.uk. For rates and information on display and classified advertising please contact our Advertisement Manager, Stewart Kearn as above.

CANTERBURY WINDINGS
UK manufacturer of toroidal transformers
(10VA to 3kVA)
All transformers made to order. No design fees.
No minimum order.
www.canterburywindings.co.uk
01227 450810

CONNECTORS, PLUGS & SOCKETS
Old & new Types
For full lists Visit Section 3
www.partridgeelectronics.co.uk

BOWOOD ELECTRONICS LTD
Suppliers of Electronic Components
Place a secure order on our website or call our sales line
All major credit cards accepted
Web: www.bowood-electronics.co.uk
Unit 10, Boythorpe Business Park, Dock Walk, Chesterfield, Derbyshire S40 2QR. Sales: 01246 200222
Send 60p stamp for catalogue

CPS Solar
Solar panels, solar cells, and many more alternative energy products for battery charging etc, please visit our website for further info or call
Tel: 0870 765 2334.
www.solarpanelsonline.co.uk

BTEC ELECTRONICS TECHNICIAN TRAINING

NATIONAL ELECTRONICS
VCE ADVANCED ICT
HNC AND HND ELECTRONICS
FOUNDATION DEGREES
NVQ ENGINEERING AND IT
DESIGN AND TECHNOLOGY

LONDON ELECTRONICS COLLEGE
20 PENYWERN ROAD
EARLS COURT, LONDON SW5 9SU
TEL: (020) 7373 8721
www.lec.org.uk

Serial LCD Displays & Controllers I2C, VT100

PIC32 with Full Colour Touch Screen

www.byvac.com

ADVERTISE HERE
CALL
STEWART KEARN
ON 01202 880299
STEWART.KEARN@WIMBORNE.CO.UK

MISCELLANEOUS

VALVES AND ALLIED COMPONENTS IN STOCK. Phone for free list. Valves, books and magazines wanted. Geoff Davies (Radio), tel. 01788 574774.

FOR SALE: Tektronix 468 100MHz Digital Storage Oscilloscope £50. Tektronix 475 Oscilloscope £40. Buyer collects Tel. 01474 325910 (Don).

ADVERTISERS INDEX

BETA LAYOUT . . . 80
BRUNNING SOFTWARE . . . 55
COAST ELECTRONICS . . . 59
COMPACT CONTROL DESIGN . . . 57
CRICKLEWOOD ELECTRONICS . . . 33
ESR ELECTRONIC COMPONENTS . . . 6
JAYCAR ELECTRONICS . . . 4/5
JPG ELECTRONICS . . . 80
L-TEK POSCOPE . . . 66
LABCENTER . . . Cover (iv)
LASER BUSINESS SYSTEMS . . . 59
MATRIX MULTIMEDIA . . . 59
MICROCHIP . . . 21
MIKROELEKTRONIKA . . . 63
PEAK ELECTRONIC DESIGN . . . Cover (iii)
PICO TECHNOLOGY . . . 33
QUASAR ELECTRONICS . . . 2/3
SHERWOOD ELECTRONICS . . . 33
SPIRATRONICS . . . Cover (ii)
STEWART OF READING . . . Cover (iii)

ADVERTISEMENT OFFICES:
113 LYNWOOD DRIVE, MERLEY, WIMBORNE,
DORSET BH21 1UU
PHONE: 01202 880299
FAX: 01202 843233
EMAIL: stewart.kearn@wimborne.co.uk
WEB: www.epemag.com

For editorial address and phone numbers see page 7

Content may be subject to change

Next Month

Ultrasonic Cleaner

Ultrasound isn't just for cleaning jewellery. Here's a much larger version; great for cleaning automotive and other mechanical parts, fabrics which cannot be machine washed, ornate bric-a-brac and a host of other hard-to-clean items.

Electrolytic Capacitor Reformer and Tester – Part 1

Got a bunch of old electrolytic capacitors you'd like to use, but don't know if they are any good? Or do you need to reform the electrolytics in an old valve amplifier or vintage radio set? This handy project is just what you need.

High-Power Reversible DC Motor Speed Controller

Here's a 12V-to-32V, 30A speed controller that's easy to build. It's available in two versions – reversible and non-reversible – and features soft start, relay switching of motor direction and PWM speed control. Just what the DC motor doctor ordered!

High-Performance Microphone Preamplifier

Some recording devices, especially computer sound cards, have poor sound quality or insufficient gain. This tiny-in-size, but mighty-in-quality module provides a line level output from an unbalanced or balanced microphone and has very low noise and distortion.

Jump Start

In sunshine-filled August's issue (we can dream), Mike and Richard Tooley build a 'Solar Powered Charger'. The fourth project in our new series dedicated to newcomers, or those following courses taught in schools and colleges.

AUGUST '12 ISSUE ON SALE 5 JULY 2012

Rechargeable Batteries With Solder Tags

NIMH		NICAD	
AA 2000mAh	£2.82	AA 650mAh	£1.41
C 4Ah	£4.70	C 2.5Ah	£3.60
D 9Ah	£7.60	D 4Ah	£4.95
PP3 150mAh	£4.95		

Instrument case with edge connector and screw terminals

Size 112mm x 52mm x 105mm tall

This box consists of a cream base with a PCB slot, a cover plate to protect your circuit, a black lid with a 12 way edge connector and 12 screw terminals built in (8mm pitch) and 2 screws to hold the lid on. The cream bases have minor marks from dust and handling price £2.00 + VAT(=£2.35) for a sample or £44.00+VAT (=£51.70) for a box of 44.

866 battery pack originally intended to be used with an orbitel mobile telephone it contains 10 1·6Ah sub C batteries (42 x 22 dia. the size usually used in cordless screwdrivers etc.) the pack is new and unused and can be broken open quite easily £7.46 + VAT = **£8.77**

Please add £1.66 + VAT = £1.95 postage & packing per order

JPG Electronics

Shaws Row, Old Road, Chesterfield, S40 2RB.
Tel 01246 211202 Fax 01246 550959
www.JPGElectronics.com
Mastercard/Visa/Switch
Callers welcome 9.30 a.m. to 5.30 p.m. Monday to Saturday

THE ORIGINAL SINCE 1994
PCB-POOL®
Beta LAYOUT

Free Stencil
Get a free SMD laser stencil with every Prototype order

WORLD FIRST!

FITS-OR-NOT
3D PCBs: Hands-on collision check

Assembly service
Even one component possible

Cool
Alu-Core IMS PCBs

Free Phone UK: 0800 389 8560
sales@pcb-pool.com

PCB-POOL® is a registered trademark of Beta LAYOUT

www.pcb-pool.com

All registered brands remain the registered trademarks of the respective manufacturer!

Published on approximately the first Thursday of each month by Wimborne Publishing Ltd., 113 Lynwood Drive, Merley, Wimborne, Dorset BH21 1UU. Printed in England by Acorn Web Offset Ltd., Normanton, WF6 1TW. Distributed by Seymour, 86 Newman St., London W1T 3EX. Subscriptions INLAND: £21.95 (6 months); £41.50 (12 months); £78.00 (2 years). OVERSEAS: standard air service, £25.00 (6 months); £48.00 (12 months); £91.00 (2 years). Express airmail, £35.00 (6 months); £68.00 (12 months); £131.00 (2 years). Payments payable to "Everyday Practical Electronics'', Subs Dept, Wimborne Publishing Ltd. Email: subs@epemag.wimborne.co.uk. EVERYDAY PRACTICAL ELECTRONICS is sold subject to the following conditions, namely that it shall not, without the written consent of the Publishers first having been given, be lent, resold, hired out or otherwise disposed of by way of Trade at more than the recommended selling price shown on the cover, and that it shall not be lent, resold, hired out or otherwise disposed of in a mutilated condition or in any unauthorised cover by way of Trade or affixed to or as part of any publication or advertising, literary or pictorial matter whatsoever.

UK designed, UK made, with pride.

Tel. 01298 70012
www.peakelec.co.uk
sales@peakelec.co.uk

Atlas House, Kiln Lane
Harpur Hill Business Park
Buxton
Derbyshire
SK17 9JL

For insured UK delivery:
Please add £3.00 inc VAT to the whole order.
Check online or give us a call for overseas pricing.

PEAK®
electronic design ltd

LCR40

The Atlas LCR (Model LCR40) is now supplied with our new premium quality 2mm plugs and sockets to allow for greater testing flexibility. Includes 2mm compatible hook probes as standard, other types available as an option.

Automatically test inductors (from 1uH to 10H), capacitors (1pF to 10,000uF) and resistors (1Ω to 2MΩ). Auto-range and auto component selection.

Automatic test frequency from DC, 1kHz, 15Hz and 200kHz.

Basic accuracy of 1.5%.

Battery and user guide included.

£74.96 + VAT
£89.95 inc VAT

DCA55

The Atlas DCA (Model DCA55) is great for automatically identifying your semiconductors, identifying pinouts and measuring important component parameters.

Just connect any way round to automatically detect MOSFETs, Bipolar Transistors, Darlingtons, Diodes, LEDs and more.

Measure transistor gain, leakage current, threshold voltages and pn voltage drops.

Now with sturdy premium probes, really tough, really universal.

Battery and user guide included.

£41.63 + VAT
£49.95 inc VAT

ESR70

The Atlas ESR PLUS (Model ESR70) is designed for testing the true condition of your capacitors.

The ESR70 will measure both the capacitance and internal resistance (equivalent series resistance) with a resolution of 0.01Ω. ESR can even be measured in-circuit in most circumstances.

Features audible alerts and automatic analysis when the probes are applied to a capacitor.

Fitted with new premium quality gold plated 2mm plugs and sockets to allow for different probes. Supplied with gold crocs as standard, other types available. Capacitance from 1uF to 22000uF, ESR from 0.00Ω to 40.0Ω.

Audible alerts!

£78.29 + VAT
£93.95 inc VAT

SCR100

The Atlas SCR (Model SCR100) is aimed at efficiently testing higher power thyristors and triacs. This tiny instrument can generate test currents from 100uA up to 100mA, covering the needs of most thyristors and triacs.

Just connect any way round and let the unit identify the type of component (Triac or Thyristor), the full pinout, the gate sensitivity and the gate voltage drop. The load test voltage is regulated to 12V, regardless of battery condition!

Now with extra long life from the supplied AAA cell!

Supplied with sturdy gold plated hook probes.

£73.29 + VAT
£87.95 inc VAT

It's only possible to show summary specifications here. Please ask if you'd like detailed data. Further information is also available on our website. Product price refunded if you're not happy.

www.stewart-of-reading.co.uk

Check out our website, 1,000 s of items in stock.

HP8560E SPECTRUM ANALYSER
30HZ-2.9GHZ with Tracking Generator
£3,500
HP8560 SERIES SPECTRUM ANALYSER Frequency up to 26GHZ
Various Models from **£2,500-£7,000**

HP83731A/B
SYNTHESISED SIGNAL GENERATOR
1-20GHZ Various Options
£4,000-5,000

TEKTRONIX TDS784D
4 Channel 1GHZ 4GS/S
Opts 05/1M/2M/2C/3C/4C no Probes
£2,750

R&S SMR 40 10MHZ-40GHZ SIGNAL GENERATOR Options B1/3/4/5/11/14/17
£POA

RACAL 1792 RECEIVER
£300

AGILENT E4402B Spectrum Analyser 100HZ – 3GHZ with Option 1DN Tracking Gen; 1 DR Narrow Res; A4H GPIB, UKB…………………………………..£5800
HP 35670A FFT Dynamic Signal Analyser 2 Channel. Unused in original box...£4000
AGILENT 83752B Synthesised Sweeper 0.01-20GHZ…………………………£6000
HP83711B Synthesised 1-20GHZ with Opt IEI Attenuator…………………..£5000
AGILENT/HP E4431B Signal Generator 250KHZ-2GHZ Digital Modulation...£2750
MARCONI 2024 Signal Generator 9KHZ-2.4GHZ Opt 04……………………....£1250
MARCONI/IFR 2030 Signal Generator 10KHZ-1.35 GHZ …………………..£995
MARCONI 2022E Synthesised AM/FM Signal Generator 10KHZ-1.01GHZ ...£500
HP8566A Spectrum Analyser 100HZ-22GHZ………………………………..£1950
HP8568A Spectrum Analyser 100HZ-1500MHZ…………………………….£1250
AVCOM PSA-37D Spectrum Analyser 1MHZ-4.2GHZ…………………………..£-
IFR 1200S Service Communication Monitor………………………………£1500
HP6624A Power Supply 0-20V 0-2A Twice, 0-7V 0-5A; 0-50V 0.8A Special price………………………….£350
AVO/MEGGAR FT6/12 AC/DC breakdown tester………………£400-£600
MARCONI/IFR/AEROFLEX 2025 Signal Gen 9KHZ—2.51GHZ Opt 04 High Stab Opt 11 High Power etc As New…...£2500
SOLARTRON 1250 Frequency Response Analyser 10uHZ-65KHZ…………….£995
HP3324A Synthesised Function Generator 21MHZ………………………£500
HP41800A Active Probe 5HZ-500MHZ ………………………………………£750
ANRITSU MS2601A Spectrum Analyser 10KHZ-2.2GHZ 50ohm……………..£750
AGILENT E4421B 250KHZ-3GHZ Signal Generator……………………£2500

HP53131A Universal Counter Opt 001
Unused Boxed 3GHZ……………..£850
Unused Boxed 225MHZ……………£595
Used 225MHZ……………………..£495
HP8569B Spectrum Analyser 0.01-22GHZ…………………………………£995
HP54616C Oscilloscope Dual Trace 500MHZ 2GS/S Colour…………£1250
QUART LOCK 10A-R Rubidium Frequency Standard……………..£1000
PENDULUM CNT90 Timer/Counter /Analyser 20GHZ…………………£1950
ADVANTEST R3465 Spectrum Analyser 9KHZ-8GHZ……………………£-
HP Programmable Attenuators £300 each
33320H DC-18GHZ 11db
33321G DC-18GHZ 70db
Many others available
AGILENT E3610A Power Supply 0-8v 0-3A/0-15v 0-2A Unused
AGILENT E3611A Power Supply 0-20V 0-1.5A/0-35V 0-0.85V Unused
HP6269B Power Supply 0-40V 0-50A ………………………………………£400
AMPLIFIER RESEARCH Power Amplifier 1000LAM8……………£POA
MARCONI/IFR 2945/A Radio Communication Test Sets with options ……………………………from £3,000
MARCONI 2955/A/B Radio Communication Test Sets….. from £625
MARCONI/IFR 6200/6200B Microwave Test Set……………………………….£-
HP33120A Function Generator 100 MicroHZ – 15MHZ Unused Boxed ………………………………………£595
Used, No Moulding, No Handle…..£395
ENI 3200L RF Power Amplifier 250KHZ-150MHZ 200W 55Db…£POA
CIRRUS CRL254 Sound Level Meter with Calibrator……………………….£95
CEL328 Digital Sound Level Meter with CEL284/2 Acoustical Calibrator………..

SPECIAL OFFERS
MARCONI 2305 Modulation Meter.£295
MARCONI 6960B Power Meter with 6910 Sensor 10MHZ-20GHZ……£295
HAMEG 605 Oscilloscope Dual Trace 60MHZ……………………………..£125
BLACK STAR 1325 Counter Timer 1.3GHZ……………………………….£95
HP8484A Power Sensor 0.01-18GHZ 0.3nW-10uW…………………………£125

ANRITSU 54169A Scaler Network Analyser 0.01-40GHZ £POA

ANRITSU 37247C Vector Network Analyser 0.04-20GHZ £POA

Many Accessories with each unit

FLUKE SCOPEMETERS 99B Series II 2Ch 100MHZ 5GS/G
………………………………. from £325
97 2Ch 50MHZ 25MS/S……. from £225

STEWART of READING
17A King Street, Mortimer,
Near Reading RG7 3RS
Telephone: 0118 933 1111
Fax: 0118 933 2375
9am – 5pm Monday – Friday

Used Equipment – GUARANTEED
Prices plus Carriage and VAT

Please check availability before ordering or CALLING IN

ROUTE FASTER !

WITH PROTEUS PCB DESIGN

Our completely new manual router makes placing tracks quick and intuitive. During track placement the route will follow the mouse wherever possible and will intelligently move around obstacles while obeying the design rules.

All versions of Proteus also include an integrated world class shape based auto-router as standard.

PROTEUS DESIGN SUITE Features:

- Hardware Accelerated Performance.
- Unique Thru-View™ Board Transparency.
- Over 35k Schematic & PCB library parts.
- Integrated Shape Based Auto-router.
- Flexible Design Rule Management.
- Polygonal and Split Power Plane Support.
- Board Autoplacement & Gateswap Optimiser.
- Direct CADCAM, ODB++, IDF & PDF Output.
- Integrated 3D Viewer with 3DS and DXF export.
- Mixed Mode SPICE Simulation Engine.
- Co-Simulation of PIC, AVR, 8051 and ARM7.
- Direct Technical Support at no additional cost.

Prices start from just £150 exc. VAT & delivery

labcenter Electronics

www.labcenter.com

Visit our website or
phone 01756 753440
for more details

Labcenter Electronics Ltd. 53-55 Main Street, Grassington, North Yorks. BD23 5AA.
Registered in England 4692454 Tel: +44 (0)1756 753440, Email: info@labcenter.com